Cognitive impacts of social virtual reality: disentangling the virtual mere presence and audience effect

COGNITIVE IMPACTS OF SOCIAL VIRTUAL REALITY

DISENTANGLING THE VIRTUAL MERE PRESENCE AND AUDIENCE EFFECT

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Abstract

Researchers have investigated the impacts of social co-presence on the individual's performance for over a century, finding that performance changes in a social setting when contrasted to performing alone – termed the social facilitation effect (SFE). Driven by the demand for realistic remote interaction, social technologies are currently aspiring to elicit a meaningful state of virtual co-presence. However, the virtual-SFE literature is currently inconclusive, especially when contrasting the AI- versus human-driven SFE-impact. This thesis argues that current virtual-SFE findings can be elucidated by investigating SFE through its mechanisms: the feeling of being observed (audience effect: AE) and the sense of co-presence with another person (mere presence effect: MPE). The three experiments tested whether AE and MPE impact participants cognitive performance differently, depending on whether the companion is human-minded or AI-driven, during either remote videoconference or lab-based immersive virtual interaction. AE was predicted to be susceptible to human-minded companion impact, the MPE to be susceptible to the visual co-presence of any humanoid companion. Videoconference-based experiment one and two demonstrated that videoconference MPE and AE were facilitatory: MPE driven by the participants self-visual presence, not companion-visual presence and AE driven by human-minded companion as predicted. The immersive in-lab experiment three found MPE and AE were inhibitory: humanoid companion presence drove the MPE, and AE was irrespective of companion mind property. Overall, the findings supported the predictions that MPE and AE can be aroused independently by changing participants beliefs about their social-companion and their observed virtual co-presence, explaining some trends in current virtual-SFE literature. However, future studies should be mindful of virtual platform affordances, participants self-presence, and real-world testing-environment when testing and interpreting results. The sufficient level of virtual co-immersion and self-visual presence is required for virtual-SFE. Hopefully this research will pave the way towards greater understanding of virtual cognition and development of wellbeing-focused virtual-platforms.

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Terms and Abbreviations

AE	***The Audience Effect*** *– social facilitation effect elicited through the feeling of being observed.*
AE-m	***Audience Effects mechanism*** *– the cognitive mechanism by which AE is evoked. The AE is evoked through the belief of being monitored by a conspecific.*
AI	***Artificial Intelligence*** *– a simulation of human mind/intelligence through a computer algorithm driven program.*
Agency	*The driving force behind the virtual character, either AI or human.*
Agent	*AI-driven virtual companion.*
Avatar	*Human driven virtual companion.*
Conspecific	*Member of the same species.*
CVP	***Companion Visual Presence*** *– the visibility of the virtual companion's presence to the participant, such as through a camera, in person, or through a virtual body.*
Ethopoeia	*A virtual interaction theory proposing that virtual companions social influence is dependent on its humanlike visual and interactive resemblance. Higher levels of human resemblance tricks people into assigning virtual companion humanlike properties and behaving towards them similar to people.*
Evaluation Anticipation	*In this thesis referred to as a state of higher arousal due to anticipation and preparedness to upcoming evaluation, see also anticipation stress page 31.*

Facilitative	*Improving task performance either in reaction times or accuracy.*
Human Mindedness	*Being a person and having a human mind, in contrast to having a simulation of a human mind, such as in the case of AI-companion.*
IVE	***Immersive Virtual Environment** – the environment in which the participant and their companion are immersed in the same 360 virtually simulated environment.*
MPE	***The Mere Presence Effect** – social facilitation effect elicited through the mere co-presence of the member of the same species within the same environment.*
MPE-m	***Mere Presence Effect mechanism** – the cognitive mechanism by which MPE is evoked. The MPE is evoked thought being conspecific co-presence in the same environment.*
Physical Co-presence	*a sense of sharing the same physical or virtual environment with someone else.*
PSS	***Performance Screen Sharing** – the real-time visual sharing of virtually performed action from own platform to companions screen. For example, solving a puzzle on your computer and projecting it onto virtual companions' device in-real-time (online).*
RRP	***Relational Reasoning Paradigm** – a cognitive performance task, engaging visual logic, used throughout the three studies in this thesis. The task measures the performance speed and accuracy on visual images matching, of shapes and patterns, to timed logical commands. The task can be performed at an easy and difficult*

levels and has prior shown to be responsive to the social facilitation effect.

SFE — ***Social Facilitation Effect** – a social phenomenon in which participants performance changes within a social context in contrast to when performing alone. The canonical SFE reported when in social context the performance of easy task improves (facilitation) and performance on difficult task deteriorates (inhibition).*

SVP — ***Self-Visual Presence** – the visibility of the participant to the virtual companion, such as through a camera, in person, or through a virtual avatar representation.*

TMSI — ***Threshold Model of Social Influence** – a virtual interaction model predicting social influence of different types of virtual humans, based on their agency (AI or human) and visual attributes, such as how humanlike is companion. The TMSI predicts that the companion is most influential if it has human agency (run by another person), irrespective of their visual attributes. If the companion's agency is AI-driven, then more humanlike attributes of companion lead to higher social influence over participants.*

Theory of Planned Behaviour — *A model of behaviour which suggests that people plan and adjust their actions adapting to a particular environmental context, depending on personal biases and expectations from the environment.*

Videoconference — *Remote virtual video interaction, which involves both video and virtual interactive functions, such as screen-*

	sharing, interactive blackboard, and other media sharing techniques.
Virtual Interaction	*Remote interaction with a social companion during which a virtual interface is used to share a real-time virtual experience. For example, virtual video interaction, desktop virtual gaming, immersive virtual reality, and mixed reality.*
Virtual Companion	*An interactive virtual social entity.*

Chapter 1: Social Virtual Reality

Literature Background and Experimental Motivation

Literature Background and Experimental Motivation

1.1 Introduction

As people develop, learn, and perform their daily tasks, they share their functional environment with other people. This social co-presence, the act of sharing a mutual environment with another person, is an inevitable part of everyday life. It may seem that social co-presence with others is inconsequential, as We are accustomed to sharing our spaces with other people. However, people, and human brains, are not indifferent to sharing an environment with others, as demonstrated by the Covid-19 pandemic. The physical social proximity during pandemic, and the lack of thereof, reshaped the relationship landscapes between neighbours and affected long-term social connections (Scott et al., 2022).

The term "physical co-presence" is described as the sense of sharing the same physical or virtual environment with someone else (Zhao, 2003). Therefore, in theory, it can be experienced both in-real world and through simulation of presence. Acknowledging the significance of social connection, and to mitigate the possible adverse effects of pandemic related social isolation, several technological approaches attempted to connect people and businesses around the world remotely. Overnight, most real-world face-to-face communication shifted to remote video messaging systems, both for work and leisure. As a short-term solution, these approaches worked. However, as the lockdowns became longer and more frequent, it became clear that the long-term reliance on this technology had adverse effects on people's wellbeing (Bailenson, 2021; Fauville et al., 2021; Okabe-

Miyamoto et al., 2021; Shockley et al., 2021) without sufficiently solving the lack of social connectedness and the increasing sense of loneliness (Dahlberg, 2021; Miyake et al., 2021; Miyazaki, 2013; Okabe-Miyamoto et al., 2021). Evidently, not only does the sense of co-presence with others matter, the level at which the co-presence is perceived matters as well. Furthermore, not all social technology is equal in its attempts to create this meaningful sense of implicit connectedness, and some technologies might magnify the perceived distance between its users.

It is crucial for people to be able to share experiences with others, and the feeling of physical co-presence amplifies the meaning of these experiences (Boothby et al., 2014, 2017). Considering that the world is moving towards a more remote, yet highly interconnected social reality, it is paramount to establish prerequisites for meaningful and wellbeing conscious connection through technology. To achieve this goal, it is important to understand how social brains process virtual interaction, and what impact this interaction has on the human brain. This understanding cannot be achieved by merely looking into the participant as a passive social observer, but rather through investigating the social perception as an interactive context between two or more people, as suggested by the approach of second person cognition (Schilbach et al., 2013). The current manuscript focuses on exactly that, by investigating how the core perceived states of second person cognition change participants' performance during different type of virtual interactions with human or artificial minds. Considering that an optimal cognitive performance is required both during remote education and work, whilst social virtual interaction is linked to cognitive strain (Homer et al., 2008), the social impact studied in this thesis is the cognitive performance change.

Learning about how different types of virtual communication are perceived is especially important now, as the understanding of what a meaningful social interaction encompasses has shifted with the emergence of new social technologies. For example, the Artificial Intelligence (AI)-assistants (Apple's Siri, Amazon's Alexa, Microsoft's Cortana, etc.) are no longer a niche accessory for the tech savvy. For many people, they are daily companions which help to navigate and organise their lives. With user reports suggesting, that although people understand the interaction occurs with an AI, the behaviour towards AI-assistants can be similar to behaviour towards a living being. It has been found that people are polite to, or get angry at, the AI assistant, assigning them personalities, and form attachments towards them (Nass et al., 1994; Nass & Moon, 2000).These human-AI relationships highlight that, with the emergence of the technologies which utilise artificial minds (e.g., chat bots and AI-assistants), and artificial bodies (virtual: AI driven agents, human driven avatars; synthetic: robots), the concept of intelligent social interaction and perceived social presence becomes augmented, and no longer limited to communication with other people. At some level, the AI companions seem to be perceived as human-like, or at least life-like. The theories of virtual interaction (the threshold model of social influence: TMSI, Blascovich, 2002) and the human-computer interaction (ethopoeia, Nass et al., 1994; Nass & Moon, 2000) offer their interpretation of such social behavioural responses to virtual companions, and the significance (the social influence) of these interactions.

Both virtual interaction theories agree that the human-like properties of the virtual others, such as their ability to verbally communicate, humanoid appearance, and the level of autonomy and realism when interacting, lead the brain to perceiving the companions similar to real people due to social heuristics. The heuristic of interacting with another person is implicitly applied to ease cognitive load when making sense of the interaction with a virtual entity who resembles another human. However, as argued in extensive reviews on virtual interaction, the level of meaningful social interaction with virtual companions also depends on the interaction context and the virtual platform used for said interaction (Fox et al., 2014; Oh et al., 2018). Indeed, even the theories such as ethopoeia and TMSI disagree on to which extent the virtual companions behavioural and visual attributes are independently influential, especially when contrasting an AI-driven companion to human-driven avatar. The TMSI argues that human agency behind the virtual entity will always elicit a more meaningful connection. The ethopoeia model, however, predicts that sufficient visual and behavioural realism of AI companion can override the social heuristic and form a meaningful connection with an AI virtual human.

Alongside augmented social companionship, the pandemic propelled the need for a more substantial sense of virtual co-presence in contrast to videoconferencing. Decades of research highlighted the potential of the immersive technologies to simulate higher levels of social co-presence for its users (Fox et al., 2014; Oh et al., 2018; Witmer & Singer, 1998). Therefore, the immersive virtual reality seemed to be the next logical step towards creating a more meaningful interactive co-presence experience. With social media companies, such as Meta (previously Facebook), investing in platforms for the wearable immersive virtual co-presence experiences, immersive virtual reality (IVR) began to make its way into the everyday households. Critically, in contrast to the videoconference-based communication, IVR does not rely on just seeing another person in a messenger window, but enables rich virtual experiences shared together in co-present virtual form, fully immersed in 360-degree virtual world. In this immersive realm, users interact with embodied virtual proxies of each other (avatars) and with other virtual agents, which are driven by a non-human mind, such as embodied AI-algorithms (agents).

In summary, this extended or augmented reality of virtual minds and bodies promises a whole new social interaction landscape, which is currently in the early stage of development, and thus highly under-researched from the perspective of its impact on human cognition. Research in this area is vital to account for any potential future side-effects of these extended virtual interactions, such as the cognitive fatigue currently related to videoconferencing, i.e., “zoom fatigue”. These technological comforts already raise questions over how the new augmented social world affects the social brain and related cognitive processes (Chattha et al., 2020).

Irrespective of uncertainty over the utility and the impact of these technologies in the future, there is also encouragement from scientific community to apply these tools, for more precise and controlled conditions, to investigate already well-established effects further. More than two decades ago, (Blascovich et al., 2002) highlighted the potential of lab based immersive virtual reality for reverse engineering real-world contexts for testing, meanwhile researchers such as Jeremy Beilenson have dedicated their decades of their careers testing virtual impacts in the lab. Although novel for household users, this augmented virtual landscape offers the researchers new approaches to test real-world effect, with rigour and control, previously unachievable without these platforms (Blascovich et al., 2002).

This thesis will demonstrate how these virtually augmented social interactions enable a new frontier of learning about assumingly well-established effects, by systematically parsing their impacts in ways unachievable in the real-world social interaction, such as separating the companions mind and their body presence. By doing go, this thesis tests how the participants subjective belief about the social interaction and perceived companions attributes, change participants' cognitive performance outcomes within a particular type of virtual reality platform. To do so, we alter participants beliefs about whether their companion is AI-minded or-human minded, at different levels of virtual co-presence, and in different virtual platforms, such the videoconference messenger and immersive virtual reality through the head-mounted display. Whether the companion has an AI, or a human mind, is established by systematically varying participants belief of whether the virtual companion is driven by a real person (human minded) or is an autonomous computer driven AI-algorithm agent (AI-minded).

The following subchapters discuss research relating to the significance of social co-presence during the real world and virtual interactions, and the theories which explain why co-presence is impactful. The chapter will be finalised with a description of the three experiments of this thesis which test the cognitive impacts of social virtual interactions virtual and real humans.

The subsequent part of this chapter (*Social Presence in the Real-Word)* highlights research supporting the importance of social co-presence in daily real-world interactions. The chapter then argues that the general environment interaction theories of intentional attitude and behavioural change do not explain the behavioural impact often observed during co-presence. In the subchapter **Social Facilitation Effect**, this thesis introduces a theorical framework which has been central to investigating the social impact of others presence, mentioning the differences of the social impact types in humans in contrast to non-human animals. Then, in the subchapter **Mere Presence and Audience Effect**, the thesis dives deeper into how for humans, in contrast to non-human animals, there are two mechanisms which elicit social facilitation effect, one based on bodily co-presence, shared with animals, the mere presence effect, and one cognitively driven, the audience effect. I discuss why the distinction is important especially in the era of extended social reality. I then introduce how virtual human interaction is perceived and how it changes human behaviour on virtual platforms depending on whether the interaction occurs with human-or-AI driven companion (**Virtual Self and Virtual Humans**). In the subchapter the **Virtual Mere Presence and Audience Affect** I review research into what is currently known about these Social Facilitation Effect (SFE) mechanisms during virtual interaction, followed by the reviewed discussion on how this interaction can be used to investigate this effect further (**Parsing Virtual Mind and Body Presence**). In the final subsection of the chapter, I will outline the three experiments which use the proposed approach, of parsing the virtual mind and body, to single out the mechanisms behind the mere presence effect and the audience effect. The significance of these findings for educational and industry applications will be briefly discussed, followed by the three experiments.

Prior to diving into the literature on mechanisms and impacts of co-presence, it is worth highlighting how co-presence impacts people's daily lives, and why the effects might not be as straightforward as it may seem.

1.2 Social Presence in Real-world

The sense of socially being with others in the same space, can be motivating, distracting, and encouraging of social connection. The developmental research suggests that from as early as infancy, learning alongside a peer motivates the acquisition of new information over learning alone (Lytle, Garcia-Sierra, & Kuhl, 2018). In formal education settings, such as classrooms, learning alongside peers boosts perceived satisfaction in learned material (Slavin, 1990), as well as motivation in learning and the quality of information retention (Pribyl et al., 2004). The mere physical presence of the teacher in the classroom, even without their explicit attendance to students, boosts discipline and task engagement in the class (Marholin et al., 1975). In work environments, the ability to work alongside others in contrast to working alone affects both job performance and satisfaction. The positive experience of a co-present environment is dependent on the type of work done alongside others(Block & Stokes, 2016; De Been & Beijer, 2014), and the individuals personality traits (Appel-Meulenbroek et al., 2022; Block & Stokes, 2016; Weijs-Perrée et al., 2018). The negative effects of socially co-present working spaces are minimized when employees have control over the level of exposure to the social workspace (Stephens & Szajna, 2015). Therefore, the controlled sharing of a physical space with others contributes to the higher wellbeing and satisfaction within a functional space. As humanity shifts towards a more remote interconnected world, the ability to simulate the meaningful level of social co-presence remotely could offer solutions for better wellbeing through social connection with others. To do so we need to understand what drives this sense of social presence.

This question of why, and how, being in the social context of others changes an individual's levels of comfort, behaviour, and performance output, has been explored from different theoretical perspectives. Prior to submerging into the SFE, it is worth noting that some of the more overt behaviour changes to the social context of others, can be explained through simple social adaptation to the perceived environment. The theories relating to general environment-based response, such as the theory of affordances (Gibson, 2014; Jones, 2018) and the theory of planned behaviour (Ajzen, 2011), roughly explains that people choose to act differently based on their perception and beliefs about the environment. Both theories suggest that how people act in a certain perceived context is mostly intentional and driven by the individual's expectations from the environment. For example, the theory of planned behaviour suggests that people plan and adjust their actions adopting to a particular environmental context, depending on personal biases and expectations from the environment. Demonstration of such intended change is more pro-social behaviour and decision making when people believe they are being watched, as this is what participants believe is assumed of them based on social expectations (Cañigueral & Hamilton, 2019; van Rompay et al., 2008). These intentional behavioural changes however do not explain why some behaviours in social context turn out not as intended, nor what is it about the mere presence with others that drives this unintentional change. For example, many of us experienced a performed task not going as well the moment someone enters the room or decides to actively monitor us during work. When watched or if someone walks into the room, people report attempting to perform at their best, but the outcome often varies from intended. This negative performance outcome during higher effort shows that the models of intentional context-based behavioural change cannot fully explain the impact of social accompanying, nor the state of higher vigilance during the experienced social situation. This suggests that there is more to social context response than meets the eye. These unexpected social impact effects have been engaging the minds of scientist for over a century and are now known under a general term of the social facilitation effect (SFE: Zajonc, 1965; Bond & Titus, 1983), first coined by Triplett (1898).

1.3 Social Facilitation Effect

For over a century, research on SFE has attempted to explain how, and why, both people (Bond & Titus, 1983) and other members of the animal kingdom (Zajonc, 1965) demonstrate a peculiar performance change in the presence of their conspecifics (a member of the same species). The impact of SFE is often reported in a particular performance outcome pattern (Bond, 1982; Bond & Titus, 1983). When accompanied by a conspecific, in contrast to performance alone, the easier and more learned tasks are facilitated (improved) and the difficult and less learned tasks performance is inhibited (impaired).

Unlike non-human animals, in humans the effects surpass just physical performance changes, and is also reported for cognitive performance outcomes in many domains. In humans, the experimental research demonstrated SFE affecting the accuracy of timed writing tasks (Schmitt et al., 1986), efficiency in learning of wordlists (Manstead & Semin, 1980), and performance changes on cognitive tasks such as the Stroop test (Augustinova & Ferrand, 2012). These experimental findings of SFE have been solidified by the years of research (Bond & Titus, 1983). In the formal real-world contexts, the SFE has been also showed to affect the working speed of employees (Yu & Wu, 2015) and performance accuracy during training (Kushnir, 1986). When discussing SFE in humans, this thesis will only focus on the SFE impact on cognitive task performance, i.e., SFE-driven performance changes on cognitive tasks (arithmetic, Stroop task, logic, etc), but not in physical tasks such as athletic performance.

1.3.1 Theories Behind the Effect

The most upheld theories of cross species SFE are structured around the arousal processes evoked in presence of a conspecific. The reasons behind the experienced arousal and their direct impact on the performance outcome are still debated. The processes are often related to a higher state of body arousal due to vigilance to the conspecific physical threat in the environment (Guerin & Innes, 1982). The early research testing SFE on simple animal models such as cockroaches, called this arousal state the “drive” (Zajonc et al., 1969). The heightened arousal (drive)was suggested to amplify the task-related dominant response in the situation. Meaning that, in the presence of conspecific, if an animal is poor at the task their higher arousal state amplifies the lack of their ability (inhibition), while, if an animal is well-trained at the task their superior performance is also amplified (facilitation). This level of arousal-driven performance change in conspecific presence has been observed even on simpler animal models such as insects, worms, mice and so on (for a review see Rajecki, 2010).

Later research, especially in more complex animals such as human and non-human primates, has highlighted additional processes which might evoke SFE alongside the physiological arousal systems. Cognitive theories explain how elements of social cognition, such as the innate tendency to monitor the conspecific and being more aware of the social dynamic, can affect the performance during social co-presence, both by facilitating and inhibiting its outcome (Guerin & Innes, 1984). Through the prism of cognitive theories, the SFE arousal is no longer just a physiological state of threat, rather a cognitive state of elevated alertness. This elevated state of alertness is often attributed to the uncertainty, vigilance, and preparedness in response to the conspecific in the environment, influencing how the animal distributes their attention and self-regulation when in physically co-present (Bond & Titus, 1983; Guerin, 1983, 1986; Guerin & Innes, 1984; Sanders, 1981). Generally, the main cognitive processes which are theorised to be interacting during SFE are: attention, executive control, and self-referential processes in response to others (Belletier & Normand et al., 2019; Bond & Titus, 1983; Guerin & Innes, 1984; Baron, 1986; Nieuwenhuis & de Kleijn, 2013; Sanders et al., 1978; Uziel, 2007). The most experimentally robust theoretical models relating to SFE during conspecific co-presence are attention-based, such as the distraction-conflict (Sanders, 1981a; Sanders et al., 1978a) and vigilance-based attention model(Guerin, 1986; Guerin & Innes, 1982, 1984). The SFE theories, such as the cognitive overload (Baron, 1986), additionally highlight the importance of executive control element in orchestrating the attention distribution between the performed task and immediate social environment, and the feedback loop between the cognitive overload and heighted arousal.

There are numerous reviews which discuss the intricacies of how these cognitive-attentional models map onto the co-presence based SFE, and the arguments pro and against these theories (Bond & Titus, 1983b; Geen & Gange, 1977; Guerin, 1986; Guerin & Innes, 1982, 1984; Sanders, 1981; Uziel, 2007). Overall, the cognitive SFE theories agree that the presence of a conspecific elicits monitoring behaviour towards them, due to either an innate automatic tendency to monitor members of the same species (distraction-conflict model: Sanders, 1981), or to resolve the uncertainty of conspecific actions in environment and prepare self for a potential encounter (vigilance-based distraction model: Guerin & Innes, 1982, 1984). The SFE is explained as the interaction between these social processes and task-related attention and executive demands. When performing in presence of conspecific, focus needs to remain on task, therefore monitoring of conspecific has to be limited, which can lead to higher levels of unease or stress (Sanders, 1981a).When performing, besides modulating the external attention towards the present conspecific, the performer also requires maintaining internal attentional resources as they remain vigilant in “stand by” preparedness mode(Guerin, 1986; Guerin & Innes, 1984). The attention and the cognitive regulatory resources are however finite (Baron, 1986), and higher stress levels have shown to detrimental effects on cognitive performance by scattering attention and focus away from the task (Eysenck et al., 2007).Therefore, as per cognitive models of SFE, when the task is difficult and requires higher level of engagement, the attention is mainly depleted on the task, although the urge to monitor the conspecific remains. The executive resources modulating the social and task-related attention get exhausted, leading to worse performance and higher stress loop. In contrast, the easy task is often automatic, not requiring a lot of attention nor higher executive demands, therefore attention flows freely between the social and on-task cues, easy task benefitting from overall slightly elevated state of cognitive arousal due to state of preparedness and vigilance (Geen, 1991; Guerin & Innes, 1984; Baron, 1986; Uziel, 2007).

In summary, in animals including humans, the physical co-presence with conspecific is theorised to heighten arousal and state of cognitive vigilance, tapping into innate conspecific monitoring processes, whilst maintaining a state of preparedness. The attention and executive cognitive resources involved to manage both the task performance and uncertainty of social environment impact task performance outcomes both by benefitting the easy task or deteriorating the difficult.

As per SFE, the conspecific co-presence is believed to impact both humans and non-human animals alike through similar attention and arousal processes. However, unlike in nonhuman animals, for people the conspecific-based cognition is not limited to immediate physical encounter. It has been shown that in people, the states of higher arousal, such as cognitive alertness or physiological stress, can be linked to more complex self-related cognitive factors, such as the subjectively perceived ability and competence on the performed task, as well as the assumed dispositions of others watching (Geen, 1991).

The SFE research has found that for people, unlike other animals, the physical embodied co-presence of the conspecific is not necessary for the SFE to occur. The SFE for humans can also be elicited through the belief of being watched when performing, even if the observer themselves cannot be seen (Dumontheil et al., 2016). This notion has led researchers to propose that, for humans, the SFE can also be elicited through the mechanisms of social evaluation, not just the state of vigilance due to uncertainty of actions of others in the environment (Cottrell et al., 1968; Zajonc, 1980). Some researchers argue that the belief of being monitored and potentially evaluated (judged) might engage similar cognitive processes, such as the state of preparedness and vigilance, similar to co-presence with conspecific(Guerin, 1983; Guerin & Innes, 1982). Whilst others suggest that being monitored, in contrast to being co-present, does not rely on resolving the uncertainty of the situation or preparing for interruption, rather on self-reflection on how the performer might be judged by others (Cottrell et al., 1968; Tennie et al., 2010). Indeed, when monitored the participants physiological arousal type within this social context changes according to how their performance might be perceived. If monitored, when task is difficult and error prone, the situation elicits a threat-based higher heart rate arousal, while when the task is easy and well performed, the arousal is cardiovascular, associated with motivation and challenge-based excitation (Blascovich et al., 1999).

As per the SFE evaluation models, the heightened state of alertness during monitoring is hypothesised to emerge from the motivation to seem competent, reflecting both on the self-competence (Carver & Scheier, 1981; Bond, 1982; Geen, 1989, 1991)and on managing own reputation in front of the potential observer (Cottrell et al., 1968). It is suggested that the easy conditions improve due to this motivation and the demonstrated evidence of optimal performance. The difficult conditions, however, due to repeated failing to achieve this goal, results in higher stress loop resulting in poorer task outcomes. As mentioned prior, the higher stress-based arousal leading to more scattered task-related attention and executive functioning (Eysenck et al., 2007).

Evaluation based SFE is believed to be human specific, due to people's ability for higher order social mentalising, such as complex social reflection on self (Bond, 1982), comparison of self to others (Geen, 1989), and mentalising over others potential dispositions towards self in real-time (Hamilton & Lind, 2016). This is in contrast to conspecific co-presence based SFE, which can occur even when conspecific is blindfolded and cannot evaluate the participant or their ability (Schmitt et al., 1986). The behavioural change to monitoring and potential evaluation is not the only subjective perception-based response that influences SFE in people.

There are several subjective self-belief factors which seem to influence the performance change. The subjective belief about task difficulty in SFE is important. When monitored, believing that the task is easy, even if it is embedded in difficult condition, benefits the outcome of the tasks as per SFE, while thinking the task is difficult, even if among the easy tasks, deteriorates its outcomes (Bond, 1982). Additionally, the self-identified personality traits, such as openness and extraversion, sometimes mediate the negative effects of SFE when watched (Uziel, 2007). As a whole, thinking about the upcoming worrisome social situation, such as an evaluation by another person, can lead to higher levels of arousal – known as the anticipation stress or anxiety (Dickerson & Kemeny, 2004; Zoccola et al., 2008; Gaab et al., 2005). During anticipation stress, the arousal level increases due to the anticipatory and preparatory cognitive processes driven by the beliefs and expectations about the upcoming event (Grupe & Nitschke, 2013; Engert et al., 2013). Neurofunctional evidence demonstrating a similar brain activation both during the stressful event, as well during anticipation of a stressful event (Hur et al., 2020). During the state of preparation to the upcoming evaluation event, referred further in this thesis as a state of evaluation anticipation, the higher levels of anticipation stress results in higher overall excitation state, leading to poorer overall performance during the actual event of evaluation (Pulopulos et al., 2020; Starcke et al., 2008).

In summary, the above literature suggests that SFE in humans is at least partially driven by their subjectively perceived social reality, based on the expectation about self-efficacy and other people dispositions about self within its context. These subjective cognitive processes are quite different to the objective performance impact when monitoring a visible physical conspecific threat, yet, not less impactful. Therefore, when monitored, a subjective belief about poor level of self-competence on the task heightens the levels of stress arousal, as the situation is perceived threatening to self-image. Whilst feeling of high self-competence on task, during social situation, is beneficial to self-image and provides a moderate level of motivational excitation. Indeed, when monitored the SFE on easy task is accompanied by a motivation based (cardiovascular), and difficult task with threat based (heartrate) arousal (Blascovich et al., 1999).

The exact mechanisms of how arousal and cognitive processing factors interact impacting SFE performance outcomes are still under debate (Wilson, 2012).

There are however indications that moderately heightened arousal is indeed motivating vigilance on sustained attention tasks (Claypoole & Szalma, 2018), whilst higher arousal states (e.g., anxiety) detriments task directed cognition away from the task and towards the stressor (Eysenck et al., 2007). Therefore, it is possible that both the arousal magnitude (Claypoole & Szalma, 2018), arousal type (Blascovich et al., 1999) and a variety of cognitive factors, discussed above, are involved in SFE based impacts. Potentially, the SFE in humans is a result of specific states of arousal and executive control demands, which can be evoked by either the co-presence or monitoring. It is therefore possible that conspecific co-presence and monitoring both orient a person towards this similar state during task performance, yet through different cognitive routes engaged by distinct social contexts. Establishing whether this is indeed the case, and how exactly this occurs, is still a goal for the social cognitive and neuroscience research to this day (Belletier et al., 2019). To progress this field further, it is important to first establish, whether the environmentally motivated engagement of cognitive processes, such as the ones involved in monitoring or co-presence, are indeed independent in eliciting SFE.

The acknowledgement that, for humans, the subjective beliefs about self and others in the environment can change the performance outcomes, is fascinating. Especially in the current social landscape of remote interaction, when it is not always clear whether communication occurs with another person (or AI-bot), and whether the person is present on the other side of the virtual end (if their camera is off, or their virtual avatar is on standby). The immersive virtual spaces also creating a sense of engulfing co-presence with virtual conspecific companions, driven by either other people or autonomous computer algorithms. With current technologies the human perception of co-presence can now transcend physical boundaries, for example through being watched on the web camera or feeling uncertainty over virtual companions' actions in the immersive space. Often, with just the belief of the social context, for example whether interaction occurs with a person or AI-agent, significantly influencing the behavioural and cognitive changes. Therefore, it is now as important as ever to revisit how perceived co-presence and beliefs about monitoring influence the cognitive performance and how these effects translate onto virtual interaction.

1.4 Mere Presence and Audience Effect

As discussed in the previous paragraphs, for humans the SFE can be elicited through two social contexts related to the conspecific: the conspecific's physical co-presence in the environment and the belief of being monitored by the conspecific. In literature these two SFE elicitation phenomena are often referred to as effects on their own. The SFE elicited through the sense of being watched, irrespective of conspecific physical embodied co-presence in the environment, is known as the audience effect (AE: Dumontheil et al., 2016; Hamilton & Lind, 2016; Somerville et al., 2013). The SFE elicited through physically sharing the same environment with conspecifics, co-presence irrespective of monitoring, is called the mere presence effect (MPE: Platania & Moran, 2001; Rajecki et al., 1977; Schmitt et al., 1986).

It is believed that humans share the co-presence based SFE phenomenon (MPE) with many other non-human animals (Guerin, 1986; Guerin & Innes, 1982; Zajonc, 1980). The monitoring-based AE, in contrast, is possibly human-specific and reliant on higher order social mentalising (Bond, 1982; Bond & Titus, 1983; Cottrell et al., 1968; Hamilton & Lind, 2016). Although both AE and MPE result in SFE, elicited through different social contexts, it is still not clear whether MPE and AE are truly independent effects. Meaning, the SFE performance change when monitored (AE) or co-present (MPE) could be aroused by two distinct independent neural and cognitive processes resulting in a similar SFE state. Alternatively, the cognitive processes involved in AE and MPE might be a part of the same social cognition spectrum. Some theories propose that the act of monitoring and physical co-presence could also lead to accumulative effect, suggesting that adding the MPE to AE can lead to higher SFE, suggesting a level of co-dependency (Guerin, 1986). Others argue that MPE and AE are driven by distinct independent cognitive processes, that in humans happen to result in a similar performance impact (change in performance; Zajonc, 1980).

Testing the assumptions of distinct cognitive underpinnings of MPE and AE, with a systematic experimental design, has proven to be challenging in the real-world environments. To do so clearly, would require an experimental contrast in which the observers mind-driven disposition, and their embodied presence can vary independently. This separation of the mind-and-body of a conspecific is difficult to achieve with high ecological validity using a face-to-face experimental paradigm. Virtual interaction, however, can systematically separate these social cues with a reasonable ecological validity and in intuitive manner. Below is an overview of how the SFE theories, discussed in detail in the previous section, map onto human specific MPE and AE. The following sections will then describe how virtual interaction can be applied to both parse the theoretically implied cognitive mechanisms behind the MPE and AE and test these mechanisms individual contribution eliciting SFE.

In the early days SFE research focused on explaining the effects seen in humans through animal models. Therefore, the first most researched social context eliciting SFE was the one that humans share with their non-human counterparts – MPE (Rajecki et al., 1977; Sekiguchi & Hata, 2019; Zajonc, 1965). It is still believed that MPE is elicited through more primitive mechanisms related to biological survival, reliant on acknowledgment of conspecifics in the same physical space, which humans share with non-human animals (Guerin, 1986; Guerin & Innes, 1984; Zajonc, 1980). Therefore, the mechanism by which the MPE is induced is physical co-presence. Co-presence based effect believed to be reliant on cognitive processes, such as the ones discussed in the SFE-theories of physiological threat arousal (Zajonc, 1965), vigilance-attention and distraction-conflict (Guerin, 1983, 1986; Sanders, 1981; Sanders et al., 1978), attention-modulation and cognitive overload (Baron, 1986). As summarised in the previous section, this co-presence based SFE, the MPE, is related to physical attention-distraction due to uncertainty and heightened vigilance over conspecific action in the environment, as well as potential state of self-preparedness anticipating conspecific engagement. In non-human primates, such as rhesus monkeys, the co-presence of conspecific has shown to improve learned task performance, the effect coinciding with higher brain activation both in the task specific and non-task specific attention modulation networks (Monfardini et al., 2016a). Similarly, in humans the MPE is theorised to not be reliant on higher-order second person mentalising, such as thinking about the disposition or judgements of others, rather on attention and vigilance-based cognitive processes and their modulation (Guerin, 1983, 1986). When measuring MPE on cognitive performance in humans, the experimental findings report performance change even when a physically co-present confederate was either blindfolded (Rajecki et al., 1977), both blindfolded and wearing soundproof headphones (Schmitt et al., 1986), or seemed pre-occupied and unable to observe participants' performance (Platania & Moran, 2001). Additionally, it seems that similarly to non-human animals, for humans the uncertainty over the conspecific action is an important factor for MPE. The findings highlight that when the co-present companion could be easily monitored by the participant, even when distracted by another task, there was no significant MPE (Guerin, 1983). There is also evidence of the state of preparedness to co-presence of another person in humans. The participants exhibit more alert pro-social demeanour irrespective whether the co-present companions' actions are seen, nor whether they are watching the participant. For example, if participants are aware of the confederate's co-presence, even if not monitored, they seem to implicitly adjust their demeanour to more visually rigid and constrained by reducing fidgeting and sitting up straighter (Guerin, 1983). This could suggest that the mere co-presence of another person induces some level of self-referential thinking, irrespective of whether companion is watching, and especially if they cannot be seen. As per MPE, this level of self-referential thinking might be driven by heighten internal attention due to the state of preparedness to respond to conspecific in the environment. This state being different to more socially performative pro-social behavioural adjustments associated with reputation management when monitored, inferring some level of evaluative judgement (Bond, 1982; Cottrell et al., 1968).

If indeed the MPE does not rely on higher order mentalising regarding confederates' disposition towards the participants or their performance, simulating co-presence alongside a interactive conspecific without the ability to mentalise should suffice to elicit MPE. Theoretically, virtual interaction can simulate such conspecific presence through a computer algorithm programmed autonomous companion. This companion would have the ability to be visually present and interactive in the environment, however, will not have a human mind to form any disposition towards the participant when monitoring. Whether this companion could indeed elicit MPE is discussed further in section: ***Parsing Virtual Mind and Body Presence.***

Unlike the MPE, the AE, is believed to be human specific and more subjectively and cognitively driven. For AE, unlike MPE, the conspecific physical co-presence is not necessary. The AE is reported in experiments in which participants cognitive task performance changes just through the belief of being monitored, without a physically visually present confederate in the environment (Frith & Frith, 2007; Hamilton & Lind, 2016; Tennie et al., 2010). The AE has been reported when showing participants an implied "live" video footage of the observer attending to participants performance, showing SFE both in adults (Somerville et al., 2013) and adolescent (Somerville et al., 2013; Wolf et al., 2015) participants. The AE was also reported by just simulating monitoring procedure, by means of blinking a green camera light signalling attentiveness towards the participants face during cognitive task performance in an fMRI scan (Dumontheil et al., 2016).

As discussed in previous section, the AE-based mentalising potentially revolves around subjective prediction of possible social outcomes of being seen, such as experiencing judgment from the observer (Bond, 1982; Hamilton & Lind, 2016). Therefore, the AE is often linked to reputation management – the portrayal and maintenance of personal competence in the eyes of others (Bond, 1982; Cottrell et al., 1968; Frith & Frith, 2007; Tennie et al., 2010). The mechanism which evokes the AE is monitoring by the conspecific. The neuroimaging studies exploring the effects of being watched, show that even during implied observation by the others, there is a heightened cortical activation in regions such as medial prefrontal cortex and striatum, hypothesised to be part of the mentalising network, and known to be active during socially comparative situation engaged in self-presentation (Izuma et al., 2010; Somerville et al., 2013).

1.4.1 Neurofunctional MPE and AE

Although the neurofunctional networks relating to MPE and AE are not clearly experimentally mapped out yet (Belletier et al., 2019a), there is some evidence of brain activation differences in MPE and AE. In contrast to attention-modulation networks shown in primates during MPE (but not motivation networks: Monfardini et al., 2016), the AE neuroimaging findings showed a significant activation in neural social reward networks (Somerville et al., 2013), as well as relational social cognition (Dumontheil et al., 2016). Therefore, the MPE could be predominantly driven by vigilance-based attention and attention-modulation related cognition, whilst the AE is driven by mentalising of others disposition and expectancy of social reward-motivation by means of social comparison.

Although MPE and AE might originate through separate cognitive processes driven by the social context, there is however a possibility that both result in similar brain state leading to SFE. As discussed above, generally the MPE and AE result in some level of self-referential excitation and stress arousal, therefore it is possible that both of these effects also share some neural structures relating to self in the second person social context. For example, both MPE and AE might involve the temporal-parietal junction (TPJ), which has been shown to activate during second person cognition integrating information about self in social context (Frith & Frith, 2007; Hamilton & Lind, 2016; Redcay & Schilbach, 2019). It is also highly likely that there are subcortical structures involved, especially when considering the role of arousal in SFE (Hamilton & Lind, 2016) and the more automatic processes of visual attention involved in MPE (Hafed et al., 2021). The precise mapping and testing of MPE and AE related neurofunctional interactions is far beyond the scope of the current thesis, especially considering that the SFE field is still divided over which cognitive processes exactly drive both effects. Hopefully, future research will build on the current findings on MPE and AE mechanisms and develop frameworks which will elucidate the cognitive and neural substrates of MPE and AE.

It is also important to note, that even if the individual cognitive processes which evoke MPE or AE are indeed established independently, the future work also needs to understand how these different social context input mechanisms orchestrate a seemingly similar physiological arousal and cognitive overload states believed to be involved in SFE. The psychosocial arousal theories suggesting that social uncertainty (such as in MPE) as well as evaluation stress (AE) both elevate amygdala activation in similar regions (Grupe & Nitschke, 2013; Hur et al., 2020).

Additionally, the research currently shows that there is an inhibitory seesaw neurofunctional interaction between the social brain hubs and task-related mechanical reasoning regions (Jack et al., 2013). How exactly these findings map onto the cognitive changes during MPE or AE is yet to be established.

MPE and AE Mechanisms

In summary, social cognition, even on the most basic level – such as social co-presence – is a more complex process for humans than animals, because it relies on complex cognitive processes to achieve social interaction. However, similarly to non-human animals, these social responses guide people's behaviours and cognitive outcomes implicitly, considering that people rarely control their arousal states during these social situations. To investigate both the MPE and AE further, and to explore the cognitive and neurofunctional underpinnings relating to these effects in the future, it is necessary to be able to separate the two phenomena experimentally. To do so, it is important to systematically separate the independent social context mechanisms that are theorised to be involved in MPE or AE.

Based on the theories discussed in this and the prior section of the current chapter, there are indeed social context-based mechanisms which could be idiosyncratic to either the MPE or the AE. The cognitive mechanism which elicits the MPE, further referred to as MPE- m, is the physical co-presence of the conspecific in the same environment. The MPE-m involves social visual attention-modulation and preparedness in response to uncertainty of conspecifics embodied co-presence in the shared environment. The social mechanism which elicits the AE, further referred to as AE-m, is the belief of being monitored by a conspecific. The AE-m involves cognitive processes such as reputation management strategies, mentalising about self-competence and disposition of others towards self.

The optimal solution to establish independence of the AE and MPE, would be to separate the MPE-m and AE-m experimentally. Specifically, to separate the visually distracting social co-presence of the conspecific from the conspecific's evaluative mind, and then measure whether these body -mind properties can elicit MPE and AE independently. Manipulating such factors systematically and with reasonable ecologically validity within a typical real-world face-to-face social context is challenging. This is where a purpose-built virtual reality approach can exceed in contrast to its real-world alternative, enabling systematic control over perceived levels of interaction such as independently manipulating a conspecific's physical presence, appearance, and social mindedness (human or artificially programmed mind).

Although MPE and AE have been researched for over a century, the notions that certain environmental social cues can change a person's performance and elicit cognitive strain without their active control, is especially worth revisiting now, in an era of virtual co-present companionship (e.g., Zoom, Teams, VR) and artificial minds (e.g., Siri, Alexa). In the following sections, I review research on how virtual companionship impacts human behaviour and performance, and how the beliefs about the agency of companion (AI-or-human minded) change the observed outcomes. The subsequent sections will then discuss how this knowledge can be used to parse the MPE-m and AE-m and test their individual contribution to SFE.

1.5 Virtual Self and Virtual Humans

The ability to immerse self within a virtual avatar body and to interact and share experiences with others virtually can be a powerful experience. Connecting through interactive animated avatars, even mediated via a two-dimensional desktop multiplayer game, is a highly valued by users and reported as community building (Barnett & Coulson, 2010). Immersing oneself within a three-dimensional environment, with a virtual body other than one's own, has shown to influence individuals' behaviours. For example, the participants behave differently when they are virtually assigned a different ethnicity (Peck et al., 2013) or an age group (Banakou et al., 2013). In education IVE's being virtually co-present with other people's avatars were reported to create a more natural flow of interpersonal cooperation between co-learners, and an increased curiosity about the learning topics (Jackson & Fagan, 2000). However, the communication within virtual realms is not limited to interacting with other people's avatars. Since the dawn of computer gaming, people interacted with virtual humans that were not driven by other people (avatars), but rather controlled by the pre-programmed computer algorithms (agents). Prior to discussing how virtual interaction with agents and avatars influences human cognition and behaviours, it is however important to consider what does the term virtual interaction entails and how it is different from other types of communication.

The definition of what truly constitutes as virtual interaction, in contrast to for example a video call, changes as the technology progresses. For clarity, in this thesis, I will refer to online video-based interaction which involves additional interfaces i.e., screensharing, collaborative blackboard, virtual background environment, and the ability to use footage of virtual humans, as virtual video interaction. This interaction type contrasts with when the communication occurs through a video between two people without any additional virtual interactive interfaces, in which case it will be just video communication. When referring to "virtual realms" or virtual interaction in this thesis, I will refer to any means of interaction that has a virtual interface component and can involve virtual humans. Virtual interaction includes desktop based two-dimensional virtual reality, such as video games (VR), virtual video interaction platforms, such as Zoom and Teams messengers, as well as immersive virtual environment's (IVE's), such as projected through headsets, and mixed reality communication, such as augmented reality or virtual CAVES. There are several reasons why it is informative to contrast virtual interaction with online video communication and face-to-face communication between people in the real-world environment.

The benefit of virtual interaction, both immersive and desktop based, is that when using a virtual platform, the interaction between a person (or persons avatar) and their virtual companion, occurs on similar interaction terms. Which means that virtual humans have more influence over the participants immediate interactive environment. From the perspective of the participant, they and their virtual companion have a similar virtual interface affordance, irrespective of whether the virtual companion is controlled by another person via avatar or is an artificial intelligence (AI) driven agent. Suggestively, during the virtual interaction, both the participant and their virtual companions are equally interactively co-present, limited or facilitated by the affordances of the virtual platform. For example, within an immersive virtual environment interface, the virtual companion can approach a participant and interact with virtual objects shared between them, as well as make changes to the rest of the co-inhabited virtual environment. During desktop-based virtual interaction, the participants actions are constrained to the same two-dimensional virtual world on the platform as their virtual counterpart. The virtual desktop-based interaction can occur either thought a computer-generated gaming environment, which participant (avatar) and virtual humans (avatars, agents) share, such as most video game platforms played on desktop computers. Alternatively, the interaction can occur through a video messenger's virtual interface in which virtual companion and participant might engage in an interactive brainstorming session whilst sharing a virtual blackboard. This video interaction method was widely used in remote teaching and work collaboration during the covid-19 pandemic, through interactive videoconference messengers such as Zoom or Teams messengers.

In all the above-mentioned virtual interaction scenarios the virtual real-time decision-making and actions can be reciprocally engaged with and monitored by both the participants and their virtual companion. This level of reciprocally equal communication is different from the real-world communication in which the interactive AI-companions embodied presence is often limited in their interactive abilities to humans. For example, the nonembodied assistant Alexa has no ability to physically approach a person unexpectedly (Lopatovska & Williams, 2018). And more embodied AI-driven robots, such as Pepper, even though are capable of approaching people, have currently very limited autonomous physical interactive capabilities or impact on mutually shared environment (Pandey & Gelin, 2018). In the virtual realms, however, virtual humans interact with the participant on virtual terms and can make changes to the mutual shared environment or physical interaction interface.

Currently, it seems that virtual companions might have more weight over participants virtual endeavours in virtual platforms than they do in the real- world environments. However, whether the virtual interaction with virtual humans is socially meaningful, and when, is still a potent question in cyberpsychology and neuroscience to this day. The virtual humans influence is especially interesting when it comes to AI-companions, such as AI-agent, that are programmed to act as people, yet are not human and lack a humanlike disposition towards participants. Yet, people do not seem indifferent towards the AI-agents.

It is possible that the AI-agents social influence resides in their visual and interactive human likeness. During virtual interaction, the virtual companion can engage the participant through embodied co-presence, irrespective of whether virtual companion is AI-or human-driven. In scenarios, in which co-presence and co-action is of most importance, the AI-agent companions have shown to significantly influence participants vigilance levels. In two-dimensional desktop games, such as World of Warcraft, the competitive interaction with AI-agents has shown to raise gamers arousal states, as measured by galvanic skin response and heartrate (Lim & Reeves, 2010). The avatar companion is however shown to be significantly more physiologically arousing even in the desktop video game. In comparison to AI-agent, cooperation and competition with an avatar companion showed higher level of physiological arousal, especially during competition (Lim & Reeves, 2010).

The higher social influence of avatar versus agent believed to be related to the higher meaning and social stakes of the interaction (Blascovich, 2002). The reward stakes are higher when competing and cooperating with another person than AI, due to possibility of being judged by another person. Indeed, neurofunctional evidence show that during desktop-based gaming, the social mentalising brain regions are more activated in interaction with an avatar than an agent companion (Johnson et al., 2015). Therefore, even in action-based gaming, the virtual co-presence and companions' disposition about the participant go hand in hand. This means that in certain social interaction scenarios the agency of the companion, whether it is driven by AI- or another person, can be a crucial factor impacting the level of virtual social influence.

Indeed, the belief about the virtual companion agency, whether it is an avatar (human mind) or an agent (AI mind), seems to change how people respond in situations where they anticipate people's judgement. For example, when sharing sensitive and demeaning information about self during video communication, people prefer to self-disclose to AI-agents, as to avoid judgement, whilst when sharing more superficial and boasting information the preference shifts towards the human-minded avatar (Pickard et al., 2016). People also seem to believe that the AI-agent does not judge them as much as real person would, therefore they do not need to withhold unpleasant personal information (Pickard et al., 2016). When doing work interviews through a virtual desktop display, the participants engaged in more reputation management with virtually interactive human-minded than AI-driven interviewer, even if people report no explicit preference to neither (Aharoni & Fridlund, 2007). The self-disclosure to another person is however more sincere when people believe that they are not identifiable through a virtual platform, such as when during online communication their cameras are off (Joinson, 2001). Therefore, it seems that even in the virtual realms, the judgement from other people seems to be a significant social factor. However, the level of virtual self-exposure during an evaluative event seems to mediate the effects of perceived judgement to an extent.

Irrespective of virtual self-exposure levels, the importance of being co-present with virtual humans within an immersive virtual learning environment seems to be socially engaging, both AI-agents and avatars have a significant behavioural altering capability, as discussed in the review by Oh et al., (2018). However, as mentioned above, the social impact (influence) of virtual companion type could be potentially social context dependent. When students within immersive virtual platform believe they are learning in an avatar co-presence condition in contrast to AI-agent, their learning outcomes increase significantly, the learning accompanied by social arousal (Okita et al., 2007). Winning against a human driven component has shown to activate the social reward regions of the brain more than winning against AI-agent (Kätsyri et al., 2013). Being deceived in joint attention game during a virtual video interaction, by implied avatar rather than agent companion, leads to differences and intensity of brain activation in mentalising networks (Caruana et al., 2016). The study on virtual SFE research by Hoyt et al., (2003) found that within the immersive virtual environment (IVE), performance on novel task pattern matching tasks decreased when users believed they were in the presence of a humanoid avatar, but not when alone or in the presence of a humanoid agent. This evidence could suggest that during meaningful events, such as learning or evaluation, the human-minded avatar companion has a higher social value and therefore influence than an AI-agent.

According to threshold model of social influence (TMSI), the higher excitation to avatars in contrast to AI-agent is believed to occurs due to participants expecting the avatar to evaluate or judge the mutual interaction from another real person's perspective (Blascovich, 2002). Therefore, interaction with an avatar companion could potentially set participants into a more alert state due to reputation management strategies. However, higher state of alertness or arousal to avatars does not necessarily mean that humanoid virtual AI-agents are not socially significant. For example, when no evaluation is expected, and the interaction occurs just based on social instincts, participants tend to follow social protocols also with AI-agents. In their study, Bailesoson et al., (2001) found that within immersive virtual environments (IVE's) people tend to respond to a physically approaching AI-agent similarly as they to another person in the real world. Suggesting that at some level there are human communication based social heuristic applied to humanoid AI-agents.

Both the virtual interaction theory of TMSI (Blascovich, 2002) and the human-computer interaction theory such as the ethopoeia (Nass et al., 1994; Nass & Moon, 2000) suggest that the humanoid virtual agents can be socially impactful. The theories agreeing thar this social influence is increased with the higher humanlike visual attributes, as well as behavioural, responsive and interactive abilities of the virtual companion. The level of social influence is however not only depending on the agent companions interactive and visual properties. A meta-analysis on agent-versus-avatar social impact reports that the immersive co-presence, such as IVE, in contrast to desktop interaction, might increase this social influence of AI-agents (Fox et al., 2014). The analysis points out that the higher sense of co-presence, facilitated by the IVE platform, reduces the gap between the perceived meaningfulness of interaction with AI-driven and a human-controlled companion. Additionally, as per meta-analysis, the most significant differences between agent and avatar impact are reported from desktop interaction studies, whilst less so in immersive co-presence interactions setting (Fox et al., 2014).

The virtual SFE research (Zanbaka et al., 2007) testing whether humanoid AI-agent can elicit SFE on maths task in an immersive virtual setting, found that agent presence can be socially influential. The researchers reported social inhibition effect on the difficult task. The maths task was performed significantly less accurately during agents monitoring presence in contrast to when participants performed alone. The inhibition effect found for the agent was not significantly different from the social impact measured in the presence of a real human confederate in the real-world environment, nor the agent in the 2D augmented projection in real-world. Another study reports that in immersive space, the virtual agent bystanders' attitudes towards the participant did influence the participants' perceived level of self-efficacy and anxiety during the performance (Qu et al., 2015). Suggesting that the presence on AI-companion can elicit more pro-social behaviours. In this study, the participants also showed an elevated heartrate, attributed by researchers to being judged by the AI-audience, when performing inside the environment with multiple humanoid AI-agents. However, as discussed above, people don't explicitly expect judgement from the AI-driven companions. Therefore, it is possible that higher heartrate and more prosocial behaviours during agents' presence is related to more self-awareness related processes of preparedness in the presence of conspecific (MPE-m) rather than mentalising processed over evaluation (AE-m). Additionally, the presence of humanoid virtual agents could have elicited more prosocial behaviours automatically due to social heuristics, as the explicit attitude statements from humanoid virtual entities reminded them of pro-social decisions (as per TMSI: Blascovich, 2002; ethopoeia: Nass et al., 1994; Nass & Moon, 2000).

It is worth noting, that as per the theories of virtual interaction (ethopoeia and TMSI), the impact of AI-agent companion is depended on their perceived humanness and responsiveness. This is supported by the literature. The humanoid agent used in the Zanbaka et al., (2007) immersive SFE study was a highly realistic agent, equipped with biological motion and audio simulation of human breathing and coughing. However, the authors argued that lack on real-time responsiveness could have weakened their SFE. Humanoid agents' autonomic or responsive motion seems to be necessary for elicitation of socially relevant processing. The study by (Garau et al., 2005) found that participants' heart rate and electrodermal activity spiked, and socially responsive behaviour towards moving agents increased, only when humanoid agents were responsive to participants, in contrast to when agents were standing still. Both Gerau et al., (2005) and Bailenson et al., (2001) also found that only when agents were interactively autonomous and responsive to the participants, the distal proximity between an agent and participants was upheld similarly to what would be expected during real human-to-human interaction. The non-interactive (motionless) agents do not seem to elicit social co-presence related arousal, as per the Wellner et al., (2010) study, reporting that when stationary human audience were edited into the IVE environment, no SFE were discovered.

The findings that people are not indifferent to virtual humans, and that responses differ based on people's beliefs about the agency of the companion, are interesting. Especially if the outcomes are not merely performative or reaction-based, but potentially implicit, such as deteriorating the cognitive task (maths) performance in virtual SFE study mentioned above (Zanbaka et al., 2007). So, what mechanisms exactly drive these SFE changes in virtual interaction. Could these findings suggest that virtual co-presence or monitoring is sufficient for impactful socially motivated response, and if so which aspects of this virtual co-presence are responsible for the observed performance change? The current virtual SFE research is not as straightforward in answering these questions.

1.6 Virtual Mere Presence and Audience Effect

The SFE of virtual humans is an interesting phenomenon. Although some studies, such as by Hoyt et al., (2003), found that SFE emerges only in the presence of a monitoring avatar, but not agent. Hoyt and colleagues report that participants performance on the visual pattern matching task got worse on difficult task (inhibition) when monitored by an avatar, with no significant difference between alone and AI-agent condition. The most research suggests that SFE can also be elicited in AI-agent presence (Emmerich & Masuch, 2016; Park & Catrambone, 2007, 2021; Zanbaka et al., 2004, 2007).

When looking into the mechanisms of eliciting SFE, the SFE induced by an avatar companion can be (at least partially) attributed to the AE-m, governed by mentalising processes (e.g., the reputation management), driven by the belief that interaction occurs with a real human. The SFE induced by humanoid AI-agents is however more difficult to interpret. Considering that expectation of higher order dispositional (evaluation) mentalising from an AI-agent is unlikely, not necessitating the reputation management strategies from the participant. Therefore, although studies report virtual SFE during monitoring by a co-present AI-agent, whether these effects are indeed meaningful as per second person condition is yet to be explored. The current virtual SFE literature, does not explain the mechanisms behind the effects, reporting only the final performance outcomes.

Reviews on virtual character interaction (Fox et al., 2014) and virtual SFE (Sterna et al., 2019; Strojny et al., 2020) also point out difficulties in interpreting the mechanisms behind the virtual human social influences. The challenges in drawing meaningful conclusions from the virtual companion literature is often attributed to the vagueness in terminology and experimental implementation. For example, as argued by Strojny et al., (2020), the research in virtual SFE is often unclear in whether real-world researchers' presence, or monitoring, might have influenced the virtual effect. Additionally, in virtual SFE studies, the MPE and AE are mentioned under a single umbrella term of SFE, making it difficult to discern the social mechanisms which drive the socially motivated changes. Furthermore, in some studies, the belief of whether companion is a human-minded avatar or AI-driven agent varies freely, without establishing participants belief about the companion. Therefore, it is not always clear what drives the SFE effects reported in many of the virtual SFE studies, especially in AI-agent conditions.

Although many virtual SFE studies have their limitation, there is experimental evidence that an AI-agent companion elicits both motivational and detrimental cognitive performance outcomes as per SFE (Park and Catrambone; 2007, 2021). During Park and Catrambone (2004, 2007) experiments, a desktop based interactive humanoid agent monitored the participants task performance on anagram, mazes, and arithmetic task. As participants performed on an in-lab desktop computer, the monitoring desktop-based presence of an AI-agent affected participant performance reaction times as per SFE. However, other in-lab studies, the AI-agent monitoring presence resulted only in inhibition, less accurate performance, but showed no facilitative effect on accuracy, both in immersive (Zanbaka et al., 2007) and desktop-based (Zanbaka et al., 2004). Some AI-agent based SFE experiments however also resulted in no socially motivated performance change. For example, in-lab experiments found that agents monitoring presence had no significant effect on arithmetic performance as measure in reaction times, both when agent was desktop present (Baldwin et al., 2016) and sharing an immersive space (Hayes et al., (2010). Whilst Emmerich and Masuch (2016) found an inhibition effect in immersive but not desktop-based virtual manipulation. This inhibition on video game attention task was demonstrated when AI-agent companion was presented on the immersive monitor (spaceship simulation), but not on the cockpit monitor in a desktop version of the task. Arguably this could suggest that co-immersion within the same virtual space with an AI-agent might be a more overall socially impactful experience in contrast to seeing them on monitor in the real-world setting.

Considering the contradictory evidence of AI-agent driven SFE, it is still not clear what exactly is socially influential about the AI-agent companion resulting in participants performance change. Given that people do not anticipate judgement from an AI-agent, it is highly unlikely that their SFE impact could be through the AE-m. This could suggest that the AI-agent SFE effects, often reported in virtual SFE literature, might be due to embodied co-presence (MPE-m) not evaluation. Otherwise, considering the inhibitory but not facilitative of effect of AI-agents, it is possible that effect is of only social distraction without facilitation. As discussed in previous sections, the classic SFE results in improved performance on easy task, and impeded performance on more difficult or poorly learned tasks. Therefore, the inhibitory effects reported in AI-agent virtual SFE could be a result of an automatic processes related to visual social distraction. Social distraction could be one of the processes involved in MPE, as per MPE-m. However, in some experiments (Zanbaka et al., 2004, 2007), it seemed that there was only social distraction, without additional the facilitatory excitation related to the state of preparedness expected in MPE.

A social distraction, due to a visually co-present humanoid entity during virtual interaction, is a possibility, considering that even a stationary unexpected human direct gaze projected on the computer monitor seems to attract participants attention (Conty et al., 2010; Senju & Hasegawa, 2005). Virtual gaze could be the main driver of such distraction. By attracting people’s attention, direct gaze stimuli have shown to increase the inhibitory demands to sustain task relevant attention, disadvantaging participants performance mostly on difficult, but also easy tasks (Conty et al., 2010). Following persons gaze is considered to be an automatic process in neurotypical population, due to its communicative and signalling value, for example during joint attention (Schilbach et al., 2010). The direct gaze towards participants has demonstrated to also induce self-referential cognition during testing (Baltazar et al., 2014), the higher self-referential thinking being related to SFE, as discussed above.

If direct gaze indeed raises self-referential cognition automatically, not reliant on mentalising, it is possible that under the right conditions, AI-agent can indeed elicit SFE through distraction. However, when testing virtual SFE using desktop based virtual humans, Park and Catrambone (2007) found that autonomous humanoid AI-agent observer produced SFE effect similar to real-human companions, without engaging in eye contact with the participants. In their study, the agent was a humanoid realistic animated companion, told to be monitoring participants performance, that was sitting to the side of the participant, looking at the participants performance screen not the participants. The experimental setup was very similar to Zanbaka et al., (2004, 2007) studies, expect in Zanbaka experiment inhibition occurred when companion watched both the participant and their performance. The only SFE study in which the companion was looking straight at the participant, with potential of mutual gaze, was the Emmerich and Masuch, (2016) experiment which showed IVE inhibition. However, in their study the agent was a humanoid robot rather than a virtual human. Therefore, although attentive gaze towards participants could be distracting and elevating their social vigilance, it might not explain the results observed in the current virtual SFE literature. Meaning that, in most current virtual SFE literature the agent is not attentively (directly) gazing at the participant, nor engaged in mutual gaze or joint attention. The real-world findings in MPE suggest that the companion presence should remain impactful irrespective of their attentive (watchful, gaze) presence.

Additionally, it is the uncertainly about the conspecific co-presence in the same environment that is theorised to drive the MPE.

The theories of virtual and human-computer interaction suggests that the visual human likeness, such as humanoid form, of the virtual interactive agents evokes the automatic application of automatic social interactive heuristics in people (Blascovich, 2002; Reeves & Nass, 1996). It is possible that through these automatic processes, the brain perceives the situation as interaction with the conspecific, eliciting a related social excitation. The humanlike biological motion, even during virtual robotics mimicking human action, have already been shown to trigger mirror neuron responses, and eliciting second person referential response (Gazzola et al., 2007). If this level of cognition can be triggered merely by referencing a humanoid form, there is little doubt that a dynamic humanoid AI-agents could elicit MPE through MPE-m's. Especially when embodied AI-agent seems autonomous whilst sharing the same virtual or immersive virtual environment. Autonomous agent can potentially also raise uncertainty over their actions during the interaction. For example, if participants cannot monitor the agent or their actions within the virtual space, when occupied by the task. If this the case, then agents can have a vigilance arousing presence, driven by a heightened state of alertness during an uncertain conspecific situation. Indeed, as mentioned prior, the AI-agents presence does not always debilitate performance (Zanbaka et al., 2007), but also facilitate it (Park & Catrambone, 2007). It is possible that in one study the agent raised more uncertainty of the situation, whilst in other they just acted as a social distraction without arousing vigilance.

Of course, the lack of significant facilitation does not necessarily suggest there was no MPE. It is likely that the studies which found only inhibition were statistically underpowered to find the effect or were influenced by the ceiling effect in easy task performance. Indeed, even in real-world SFE, the easy task facilitation is rarer than inhibition of the difficult task (Bond & Titus, 1983). When comparing the sample size of the SFE studies which found canonical SFE (Park & Catrambone, 2007, 2021) to the experiment which did not find SFE or resulted just in inhibition, an insufficient experimental power in the other studies could be a possibility. This is especially a possibility considering that for examples Zanbaka et al., (2007) reported a trend towards easy task facilitation but were unable to detect a significant effect.

Based on the virtual SFE literature discussed, it seems that AI-agent companions can elicit SFE under the right circumstances. It is possible that this performance change occurs through the MPE-m route. Further testing needs to be conducted to conclude if an AI-agent can indeed elicit MPE, without AE. The current thesis will test this hypothesis by systematically operationalising the visual presence of the companion within the virtual settings. In the current thesis the companion's visual representation and presence, as seen through the participants interactive platform, will be termed Companions Visual Presence (CVP). The CVP levels will be contrasted with other factors to establish the driving mechanisms behind virtual SFE.

Additionally, it is important to re-state that, as discussed in the ***Virtual Self and Virtual Humans*** section above, people expect different mentalising abilities from AI-agents and avatars. Therefore, the participants might respond to agents and avatars differently depending on the social context in hand. It is possible that the AI-agent and human-driven avatar will impact participants differently, depending on whether the effect of interest is AE, reliant on the companions monitoring (AE-m), or MPE, reliant on co-presence (MPE-m). There are no previous published findings that systematically separate the AE-m and MPE-m when investigating AI-agent and avatars social influence on participants performance. The current thesis focuses on exactly that. Without separating these mechanisms, it is difficult to discuss how these virtual companions engage the social brain and elicit SFE.

Besides the influences of the virtual companions' mind or co-presence properties, it is also not clear whether SFE can occur if the participant does not feel visually present themselves. The sense of self-presence, being visually or physically present in the environment to companion, during face-to-face interaction is considered a *status quo*. Yet arguably in the virtual reality this level of self-exposure would not be ignored. As mentioned earlier, being identifiable changes how open people are at sharing more private and shameful details about themselves (Joinson, 2001). Measuring the impact of being visible or physically present alongside others could unlock a deeper understanding of the essence of companionship-based arousal such as the MPE and AE – by asking, whether there can be a meaningful us, without the physically present self. Although overlooked in the real-world, the level of self-presence, referred to in this thesis as the Self-Visual Presence (SVP), is an important aspect of virtual interaction domain. Often in virtual platforms, the visual identifiable self, SVP, can be switched off with a button click or occluded by an avatar. The ease of turning self-presence on or off in virtual interaction, of course makes the testing of its impact more straightforward and ecologically valid in contrast to real-world communication, in which active occlusion would be required.

1.7 Parsing Virtual Mind and Body Presence

One of the clear examples of where virtual platforms aid in understanding cognitive processes is experimentally controlling the perceived levels of the self and others within a virtual interaction context. In virtual environment, using a person's avatar permits the researcher to alter the individual's self-image and physics of their virtual body, rapidly and with high ecological validity of virtual interaction. As discussed above, having an avatar which is visually different than oneself can be behaviourally changing experience. The same level of mind and body separation can be applied to interactive social companions, with addition that a companion does not necessarily need to have a human-mind, such as the AI-agent (Sutskova, Senju, & Smith, 2022. In real-world testing, it is near impossible to separate a person's mind from their body's ownership, without significant intervention. This level of virtual control enables researchers to test the driving forces of communication by reverse engineering and parsing its components. For example, by controlling the levels of companion visual humanness, such as their virtual body type, or their driving force, the agency companion (another person, or AI-algorithm), it is possible to test the impact from the affordances of these interactions.

Additionally, during the virtual interaction, the researcher can control the level of self-exposure the participants contribute to the environment, for example whether they themselves or their performance can or cannot be seen. In the online video communication method, the video or performance channel can be turned on or off at a cue, for either of the communication members, for as many mixed trials as is required for data acquisition. In immersive environments, the participants realistic self-presence is occluded and represented virtually by different types of avatars. The self-visual presence through avatar might vary, such as the avatar can be either an identifiable character which visually mirrors their user, a functional first-person perspective which interacts with environment without a tangible body presence, or an avatar with different appearance which masks the user's true identity.

The self-visual presence, SVP, can be an important factor in virtual SFE. This is especially true for the AE, when the person must believe they are being observed or judged. For the perceived others disposition to self to occur, their self, or at least their identifiable performance needs to be seen by another person. Currently, most online social platforms encourage their users to have some level self-visual presence during communication, either in picture, live video or interactive avatar form. Research suggests that when the participants believe they cannot be identified, their decision making becomes less pro-social (Seo et al., 2017), in contrast to the findings when people believed that they can be seen increases pro-social behaviour. It is arguable whether the self-visual presence, or the sense of visual self-exposure, is also important for the virtual MPE to occur, or whether the visual presence of the companion is sufficient to elicit the perceived state of co-presence.

1.8 General Summary

In this chapter I have discussed the importance of being physically co-present with others whilst sharing experiences, and what being co-present means in the current virtually augmented world. I then discussed the effects which are perceptually related to social co-presence. I have discussed how social mechanisms engaged in these effects affect the attention and performance outcomes of the non-social tasks performed within the social context. Given the growing interest in maintaining and facilitating the cognitive abilities in social settings, such as education and work, I have focused on the cognitive performance changes driven by social cognition demands.

The main effect discussed in this chapter was the social facilitation affect (SFE), which is believed to be elicited either through two processes, either the physical co-presence of the conspecific (member of the same species) in the same environment, or through the belief of being monitored by a conspecific. The two processes that elicit the SFE are known as effects on their own, the physically co-presence driven effect is known as the mere presence effect (MPE), the monitoring from afar effect is known as the audience effect (AE). I discuss how the cognitive and arousal mechanisms related to MPE, the MPE-m, and AE, the AE-m, lead to the state of excitation resulting in the SFE. The SFE effect on performance resulting in better performance on easy task and worse on difficult during the social context in contrast to performing alone. The MPE-m's are related to physical body co-presence with others in the same environment, reliant on cognitive processes such as attention-distraction, attention modulation, state of vigilance, uncertainty and preparedness related to the conspecific action during co-presence. The AE-m is related to being monitored, relying on cognitive processes such as mentalising over dispositions of others about the participant and their performance, potentially engaging reputation management related strategies and stress or motivation arousal.

I have then discussed how AE and MPE are elicited in real-world situation, and why it is believed that the social mechanisms eliciting these effects are independent. Followed by what is currently know about the virtual elicitation of these mechanisms alongside virtual humans. I describe the immersive and desktop based virtual SFE, using avatars and agents. Demonstrating that it is still unclear how agents and avatars elicit SFE, and whether these effects are elicited through the MPE-m or AE-m. Based on the previous studies in virtual humans I speculate that AE can be elicited with monitoring by avatar, whilst MPE with embodied visual presence of a humanoid AI-agent companion. Finally, I describe how virtual platforms and interactions with virtual humans can be used to learn more about the social brain within the virtual realms as well as about the classic effects such as MPE and AE. I briefly discuss that when testing in virtual realms it is important to keep track of whether participants themselves feels like they are present in the environment alongside the companion, in this thesis participants presence is discussed in the terms Self Visual Presence (SVP). The visual embodied presence of the virtual companion, as seen from participants perspective is referred to Companion Visual Presence (CVP).

The main take home message is that research shows that people are not indifferent to virtual humans, both AI-and-human driven. However, the participants responses seem to differ depending on the agency of companion, i.e., whether they are AI or Human-driven. People seems to acknowledge the virtual body presence of AI-driven agents and physically treat them as human-like. However, when it comes to more meaningful interaction which might compromise self-reputation, such as negative self-disclosure, people withhold opening up to human-driven avatars, and less so with AI-agents. Therefore, it seems that there is a difference in social influence related to virtual human's mind and their body presence. However, the analysis of this impact, has not been yet approached in a systematic depth required to understand the driving factors of these impacts. The virtual SFE studies often report a social impact, although the direction of the impact is not always canonical SFE, with some studies showing facilitation whilst others just debilitation of cognitive performance. Based on the current research, it is still difficult to conclude which aspects of interaction with virtual humans, and at which virtual platform levels, are sufficient to generate the social impact observed in the real-world MPE and AE. Additionally, it is not clear whether the representation of self-presence within the virtual interaction is an important factor contributing to the effects.

The three experiments in this thesis, described below, attempt to tackle several aspects of the phenomenon of SFE with virtual humans, at different levels of self-and companion presence, during a videoconference and within an immersive virtual environment.

1.9 Predictions and Experiments

This thesis focuses on the two baseline second-person cognition effect which result in SFE (Hamilton & Lind, 2016). One effect is the driven through cognitive mechanism related to sense of co-presence, known as the mere presence effect (MPE). And other effect is driven by the cognitive mechanisms relating to the state of being watched, known as the audience effect (AE). The main question is whether the social impacts (SFE) elicited through the mechanism involved in these effects, AE-m and MPE-m, often reported in the real-world, can be achieved virtually and independently. And whether participants will respond similarly to artificial humans as they do to real people. This question is tackled in three novel experimental paradigms, with two studies utilising a conventional videoconference-based interaction method (virtual video interaction), and one tested within an immersive virtual environment (IVE). The videoconference method (experiment one and two) is conducted in virtual video interaction platform, the Zoom messenger, which was widely used throughout the covid-19 pandemic social distancing procedures. The immersive virtual environment (experiment three) is developed in Unity game engine, used to create immersive interactive gaming experiences. The purpose of the developed interactive paradigms is not only to elicit MPE and AE, but also to parse the impact based on the predicted mechanisms related to these effects, MPE-m and AE-m, both by isolating these mechanisms and testing their accumulative and additive impact.

The social impact of virtual interaction for each experiment is measured via the task performance outcomes on a cognitive task. As mentioned in the introduction, the cognitive performance was chosen as its optimal performance is desirable during virtual interaction, yet virtual interaction can interfere with it (Homer et al., 2008). The real-time cognitive changes are measured and analysed through the theoretical prism of SFE, suggesting that in social context in contrast to performing alone, the performance on easy tasks gets better (facilitation) and performance on difficult tasks gets worse (inhibition), see **Social Facilitation Effect** section above for discussion on the mechanisms that drive this performance fluctuation. The cognitive task chosen to be performed during the elicited social states is the relational reasoning paradigm (RRP). The RRP is a timed non-verbal visual logic task that employs the executive and working memory cognitive functions (Dumontheil et al., 2010).There are several reasons for choosing this task: the RRP measures real time cognitive reasoning and is easily adaptable cross-platform, is not dependent on verbal processing, is novel and learned just before the experiment, and has been proven to be susceptible to SFE in real-world testing (Dumontheil et al.,2016).

The virtual companions' social impact levels are predicted based on the model of virtual cognition and perception, which explains the interaction between companion agency and virtual their virtual presence – the threshold model of social influence (TMSI: Blascovich, 2002) and the theory of ethopoeia (Nass et al., 1994; Nass & Moon, 2000). Although, both models overall predict that the virtual interactions social impact is dependent on the interactive realism of virtual companion, TMSI highlights the importance of human-minded companion agency during interaction. The measures of overall social influence are analysed exploratorily alongside the main question of social facilitation of virtual others. The analyses are inspired by the evaluation anticipation phenomenon, suggesting that anticipating evaluation from a meaningful source might raise overall level of arousal during the time of anticipation, even prior to the evaluation event occurs. Besides the social impact of accompanying companions themselves, this thesis argues that the virtual representation of self (self-visual presence: SVP) is important for the social facilitation effects to occur in virtual reality. The factor of self-visual presence is considered throughout the research in this thesis, and explicitly tested in one experiment. The theoretical support for prediction on how AE-m and MPE-m impact participants performance through intentional behavioural changes, such as increasing efforts on performance in social setting, is based on several theories, such as the theory of planned behaviour (Ajzen, 2011) and the reputation management theory (Geen, 1991). The implicit effects driven by the MPE-m are predicted based the several cognitive theories relating to attention, vigilance and preparedness in conspecific co-presence (Baron, 1986; Driver et al., 1999; Guerin, 1986a; Sanders et al., 1978). The implicit effects driven by the AE-m are predicted based on the evaluative models of AE (Cottrell et al., 1968; Sanders et al., 1978). The expected outcomes of performance fluctuation are reliant of the theory of SFE, which is the central impact of interest in this thesis.

There are two main questions examined throughout this manuscript. First, whether the mechanisms of AE and MPE, such as the MPE-m and AE-m, will elicit SFE independently through the interactions with different virtual human companion types. The companion types being assigned based on virtual companions' level of visual presence (CVP) and mentalising property (agency), such as having a human-mind in contrast to an AI-mind. According to the prior literature, the prediction is that the visual presence (CVP) of a humanoid companion, irrespective of their agency (AI, human mind) can elicit SFE through MPE-m. The AE based SFE is expected to be elicited by a monitoring (AE-m) companion with a human-mind evaluation ability, but not an AI-driven companion without an evaluative mind. The second question is whether the virtual medium, such as the desktop-based videoconference virtual interaction or immersive virtual interaction differ in how MPE and AE impact participants performance. Based on the literature, both the MPE and AE can be elicited in either of these virtual environments. However, due to higher sense of immersive co-presence with a partner inside the IVE, there is a higher likelihood that the MPE will be prominent in IVE. Additionally, it is possible that due to self-visual presence being more realistic in video-based virtual interaction, the effects which rely on reputation management, such as the AE will be more prominent in videoconference study, when participant is visually present as an identifiable self. Unless the virtual MPE also necessitates a sense of realistic self-visual presence (SVP), eliciting a state of preparedness and exposure to virtual companion. If so, then being self-visually present through a video whilst performing could be impactful irrespective of whether participant can see the companion, as long as participant themselves feel exposed to the potential companion due to turned on camera. The three experiments following this chapter investigate and test these questions.

Experiment one (**Chapter 2**) focuses on how the video co-presence with different types of companions (video of real-human, avatar, or AI-agent) impacts participants performance on a cognitive task. During performance the participants are identifiable and self-present in the video, whilst screen-sharing their performance on a cognitive task to the companion through the Zoom messenger. The companion is either watching them (attentive) or is visually present but with their back turned away (non-attentive). The experiment one tests visual co-presence where the participant is fully self-visually present realistic self in their home environment streaming themselves through video, however their companion co-presence in the participants environment is merely visually streamed through a messenger video window. The companion types are a realistic real-human video of the researcher, an interactive avatar which maps onto the researcher, or and AI-agent who is visually identical to the avatar but is believed to be controlled by an AI. This experiment focuses on the general contrast of co-presence versus absence of both companion and participant during the performance (MPE), and then contrasts the attentive co-presence of companion with participant visually present and performing versus when non attentive (AE). For this experiment we establish whether MPE and AE, can be elicited in their holistic predicted form through their independent mechanisms MPE-m or AE-m, accordingly. This experiment does not separate the self-visual presence from the presence of companion. The AE is expected only in attentive human-minded companion groups (real-human, avatar) but not in the AI-agent group. The MPE are predicted for any co-presence with companion, irrespective of their mind property. The overall effects of performing under the influence of companion are explored.

Experiment two (**Chapter 3**) extends on the first experiment and focuses on parsing the predicted social impact components related to MPE and AE. The three elements of videoconference-based interaction vary systematically through the experiment. The three components are the companion visual presence, participants self-visual presence and visually visible performance screen-sharing. All conditions interact with each other, as the levels are either turned on or off systematically. For AE the participants believe that when performance is visible (performance screen-sharing) the companion can attentively monitor their performance (AE), if both participant and their performance is visible the companion could attentively monitor both. Otherwise, if the performance is not visible, the participants can be just merely visually present, when they perform, without being judged for their performance. The MPE-m impacts are tested at three levels, MPE effect of self-exposure presence irrespective of whether companion can be seen (self-visual presence, SVP), the companion's visual mere presence irrespective of whether the participant is seen (companion visual presence, CVP), or participant and companion being visually present together (the full co-presence MPE), attempting to replicate the result of experiment one. By switching the levels of self and companion exposure during video conference, we investigate which virtual social exposure levels contribute to the emergence of the MPE and the AE during an online videoconference-based interaction. For the MPE, the impacts are tested both irrespective of performance monitoring, as in experiment one, and under higher control when the performance is definitely not monitored (cannot be seen). For the AE, the impact of AE is tested as just performance visibility (just performance screen-sharing being on versus off), first irrespective of participants self-visual presence, and as an accumulative or additive effect of being monitored whilst performing. As mentioned in the **Mere Presence and Audience Effect** subchapter above, the companion's visual presence should not be important for AE-based SFE to emerge. However, due to potential distractive or additionally facilitating nature of seeing the monitoring companion (see **Chapter 3** for more information), an exploratory analysis on whether the CVP would contribute to the AE has been conducted. Since the experiment one showed that the avatar companion (human driven virtual companion) was the most ambiguous of the companions in impact during the AE, we decided to test with avatar companion only. The decisions to focus on avatar companion was made with consideration of mapping the findings in videoconference-based experiment within an immersive interaction with virtual companion types (virtual agent and avatar, not realistic human) in experiment three **(Chapter 4).** Additionally, the presence of an avatar with a mentalising property, provides a more poignant separation of the companion with a habitual human mind-disposition, yet an unusual for participant's virtual body. This contrast was expected to amplify any potential social visual distraction effects that could be experienced with a real-human video companion. The decision was also time sensitive, in the future the experiment should be extended with real-human and AI-agent presence, testing whether there is indeed a difference due to visual attributes of the companion in videoconference-based interaction.

In experiment three (**Chapter 4),** the thesis tests the impact of companion visual presence (CVP) type in more depth, testing whether the overall companion co-presence in the virtual environment matters, but also whether the humanoid type of CVP, versus non-humanoid social companion presence, would drive the effect. The IVE tested AE and MPE with virtual humans, exploiting the fact that realistic co-presence in immersive spaces is currently technologically impossible. In experiment three the participants perform the cognitive task under a higher level of co-immersion (i.e., in an immersive virtual environment) in contrast to videoconference-based interaction. Similarly, to experiment one, the companion is either human-or AI-minded and has different types of levels of visual presence alongside the participant, either none (no visible companion), non-humanoid (an interactive monitoring camera, or humanoid (a virtual human). However, due to technical limitation of IVE during testing, the level of co-presence in this IVE study is different to videoconference-based study, due to participant not being realistically self-present in the environment. This means that, although in immersive experiment the participants now share the same virtual mutual space with the companion, which heightened the perceived level of co-presence in comparison to videoconference-based studies. In contrast to videoconference-based experiments, the participants are immersed into the IVE under lower levels of self-visual presence, due to virtual headset occlusion of their face. In experiment three, the participants were given a functional self-presence, they were perceptually sat behind the desk, whilst being led to belief the companion can track their gaze and head position as well as their performance withing the environment (see **Chapter 4: Introduction**). Experiment three tested whether it is possible to facilitate SFE through separate AE-m and MPE-m when self-visual presence representation is low (functional, not visual), however the simulated level of being virtually co-present in the same space with the companion is high. If this more functional state of self-visual presence is sufficient to generate the state of co-presence, then the AE should emerge when a human-minded companion observers the participant's performance. Additionally, if companion visual presence alone is sufficient alongside the participants functional self-presence through the sense of higher co-immersion, there could be MPE-m led SFE irrespective of companion's visual presence type (humanoid, non-humanoid), as long as they are present, versus when companion is not visually seen in the environment). However, as per the threshold model of social influence (Blascovich, 2002) and ethopoeia (Nass et al., 1994; Nass & Moon, 2000), the impact might rely only on the presence of humanoid companion. As with the previous two studies, we explored the overall influence of companion types throughout the study.

I hope that the findings from these three studies will elucidate the most impactful aspects of virtual social interaction on the foundational level of social cognition. The results will hopefully pave way for more complex models of human social perception during virtual interaction, accounting for these baseline states and their impacts. The results of these findings should also be considered when building socially motivated work, education and wellbeing-based platforms, with human perception and cognitive strain in mind. Prior to discussing the elements which contribute to MPE and AE, and with which companion, it is important to establish, whether the SFE can actually be elicited during virtual communication, the next chapter focuses on exactly that.

Chapter 2: Experiment One

Videoconference Mere Presence and Audience Effect:

Human, Avatar, Agent

Videoconference Mere Presence and Audience Effect:

Human, Avatar, Agent

2.1 Registered Report and Pre-Registration.

The current chapter is a thesis adjusted transcript of our peer reviewed published open access article: "Impact of Video-Mediated Online Social Presence and Observance on Cognitive Performance", Sutskova, Senju and Smith, 2022. Prior to data acquisition and analysis, the experimental and theoretical propositions of the current experiment were peer reviewed and preapproved as a registered report in an American Psychological Association (APA) journal of Technology, Mind and Behavior, 2020.

The literature review, research questions and hypotheses presented in the current chapter, as well as experimental design and the analysis plan of the current experiment, were preregistered within the Open Science Framework (OSF): https://osf.io/mbrzt. The supplementary material for the current experimental design, such as the pipeline of testing can be found on the pre-registration link: https://osf.io/wr9zg.

I would like to thank our then placement student Billie Dale for her diligence and time whilst testing the participants for the current experiment online during the difficult time of Covid-19 pandemic.

2.2 Introduction

Since the COVID-19 pandemic onset and the subsequent lockdowns, many people have had to shift their habitual education, social and working environments into their homes, connecting to the rest of the world remotely through video chat and other virtual media. Adaptation to these sudden changes has led to novel digital interaction practices. Anecdotally, some people preferred to work alongside live videos of their colleagues operating in the background, stating that the practice is motivating and keeps them more focused. The empirical findings support this motivation, suggesting that the presence of other people seems to indeed magnify participants' subjective perception of their efforts on tasks, as well as increase the belief over their effort exertion to the teams' accomplishments (Steinmetz et al., 2016). The Social Facilitation Effect (SFE: Zajonc, 1965) also demonstrates that these effects are not solely subjective, as both social behaviours and task relevant cognitive processes are altered in the presence of other people (Bond & Titus, 1983; Claypoole & Szalma, 2018; Cottrell et al., 1968; Platania & Moran, 2001; Rajecki et al., 1977; Schmitt et al., 1986; Wolf et al., 2015).

Considering the increased interest in videoconference-based interaction propelled by the COVID-19 pandemic, this first experimental chapter focuses on the online videoconference co-presence impact on the participants' cognitive output. Additionally, the current study considers the growing industry interest in virtual human interaction, both with AI-and human-controlled companions, testing how these interactions differ in their social impact. The paradigm exploits virtual interaction as a tool to separate the perceived companions mind from the virtual body (see *Introduction: Parsing Virtual Mind and Body*), whilst investigating the impact of different virtual companion types (video with a real-human, avatar, agent) on participants cognitive performance outcome. The cognitive performance changes are measured whilst the participants perform alongside a merely video co-present but not attentive companion or a performance monitoring virtual companion. The current experiment explores these cognitive impacts, alongside virtual companions, through the prism of the Social Facilitation Effect (SFE). The cognitive task used in the current experiment, and throughout the three studies of this thesis, is relational reasoning paradigm (RRP). The RRP consists of rapid visual pattern matching exercises (see Methods), based on on-screen commands and relies on executive control and non-verbal reasoning. The pattern matching is presented at easy and difficult levels of task performance, the task outcomes are measured in accuracy and reaction times of performance. The task has shown to elicit SFE in the real-world camera observation setting (Dumontheil et al., 2016). The current chapter focuses on eliciting cognitive task based SFE performance change through two separate effects related to SFE – the Mere Presence Effect (MPE) and Audience Effect (AE). To do so, the experiment operationalizes the two mechanisms which are theorised to elicit MPE and AE independently. The MPE is theorised to be elicited through the mere presence effect mechanism (MPE-m) of the co-presence with conspecific, and the AE through the audience effect mechanism (AE-m) of being monitored by a conspecific companion.

Research shows that the sense of being monitored through a video improves (facilitates) attention to task (Miyazaki, 2013), and elicits more demonstrative pro-social behaviour (Cañigueral & Hamilton, 2019; Izuma et al., 2010), as well as increases effort of task (Bradner & Mark, 2001). However, during virtual interactions, people's behaviour differs based on who they believe is behind the interactive observing gaze. When interacting with virtual companions, the self-disclosure of personal information becomes more moderated when participants feel identifiable to an occluded human-minded observer, such as by an avatar, although less so when the companion is an AI-agent (Joinson, 2001). The trust levels between avatars seem to be overall similar to trust between real humans, yet the brain seems to mentalise less when interacting with avatars than a real human (Riedl et al., 2014). The interaction with AI-driven agents reduces some levels of loneliness (Ring et al., 2015), however the subjective attitudes towards agents are still casting doubt on their meaningful social impact (Loveys et al., 2019). The theories of virtual (threshold model of social influence: TMSI, Blascovich, 2002) and human computer interaction (Nass & Moon, 2000c) suggest that virtual humans, with humanlike interaction and the visual properties, can be socially influential due to the automatically applied social heuristics people apply when interacting with them. Whether this influence is driven by the mere virtual human-like presence or assumptions of mentalising, and for which virtual companion type, is to be determined.

The studies examining the social impact of virtual embodied agents and avatars on the cognitive performance of human participants have looked into the phenomenon of SFE with inconsistent results. Research of SFE within Immersive Virtual Environments (IVE) predominantly reports improved cognitive performance when participants believe they are in the presence of humanoid avatars, but not agents (Hoyt et al., 2003; Okita et al., 2007). Other studies, however, report that agents' presence elicits SFE (Park & Catrambone, 2007; Zanbaka et al., 2007), as long as the agent is humanoid (Garau et al., 2005) and displays human-like motion (Wellner et al., 2010). There is still requirement for a systematic analysis which virtual humans elicit the observed behavioural and performance changes, and most importantly through which cognitive routes and why. The impact trajectories behind the virtual SFE would be more easily determined if the SFE impact was elicited independently through the two established mechanisms of the SFE, the MPE-m of co-presence with the companion irrespective of mentalising property, and the AE-m, the sense of being watched by a mentalising companion. Through operationalisation of these mechanisms, we can establish the distinct factors contributing to social influence of different types of virtual others.

In the experiment presented in this chapter, we tested whether it is possible to elicit the MPE and AE during videoconference interaction, contrasting how the real-time video-based co-presence with agent, avatar and a real-human (live video) companion impact participants' cognitive performance. Throughout the experiment the participants were exposed to one of the three types of social companions as they perform a cognitive task through a currently widely used online video messenger software – Zoom.us. The participants performed the paradigm remotely from the comfort of their homes. The videoconference software is used as a virtual video interaction platform in which participants can share their live video as well as desktop screen remotely with their virtual companion.

The current study was designed to test whether the videoconference interaction with different companions can elicit SFE through MPE-m and AE-m independently, when the participant is not physically in the same room with their virtual social companion. This is done by systematically manipulating the social context as perceived by the participant, informed by the hypothesised cognitive processes underlying MPE and AE in the real world (see chapter one **Social Facilitation Effect**). The two perceived social contexts are: the state of being monitored by the companion whilst sharing task performance on screen (AE-m) and being merely visually co-present with the companion during task performance whilst the companion is not attending to the participant nor their performance (MPE-m). During monitoring the companion is watching the participant and their performance. During the co-presence the companion is video-present alongside the participant performing the task, however the virtual companion has their back turned to the camera and is not attending to the participant nor their performance.

Importantly, the current study was not designed to test which level of self-exposure (self or performance visibility), or companion video presence (visible or not) contributes to these effects. The parsing of these MPE-m and AE-m contributing factors is the focus of experiment two (**Chapter 3**). Instead, the current experiment focuses on sufficient elicitation of MPE and AE through their independent mechanisms. We do so by systematically contrasting cognitive performances between the social contexts which should selectively engage MPE-m and AE-m with those which should not. The MPE and AE depended performance changes are predicted based on the different virtual companion type characteristics, and the software affordances of the messenger, such ability to switch off the visibility of interaction with the companion.

As discussed in the chapter one (**Parsing Virtual Mind and Body Presence**), the distinction between a human-minded avatar and a not human-minded AI-agent generates separate predictions for AE and MPE, which are hypothesised to be driven by different social mentalising processes. This is where the virtual interaction parsing is significant. Whilst both the embodied agent and avatar might share the same visual features (both in form and motion), the distinguishing feature of an avatar over an agent is its ability to judge participants' performance from the perspective of another person (human mindedness). As explored prior, people do not expect AI-driven companion to exhibit judgement in as way a human counterpart would (Gratch et al., 2014; Pickard et al., 2016). As the AE is hypothesised to be (at least partially) subserved by mentalising over others' judgment during monitoring, we would expect AE-m to be engaged in eliciting SFE in an avatar (i.e., a counterpart with the capacity for social judgment), but not agent condition.

In contrast to AE, which requires a companion with a human mentalising property, the MPE is theorised to be driven by attentional processes engaged due to uncertainty over the actions of co-present companion, such as in preparedness for potential engagement (see **Introduction: Mere Present and Audience Effect**). Although AI-agents are mostly not expected to exhibit judgement, the interaction with an embodied agent does seem to engage social attention and at some level even social-reward brain networks (Pfeiffer et al., 2014). As discussed, this activation could be related to the social heuristic application to humanlike interaction, while consciously understanding that communication occurs with non-human “mind”, proposed by the virtual interaction theories (Blascovich, 2002; Nass

& Moon, 2000). Considering that the mechanisms underlying MPE are hypothesised to involve social attention related processes towards the co-presence of other people, it is possible that the autonomous visually present AI-agent, similarly to human controlled avatars, might elicit MPE when contrasting to performing alone.

Contrasting a visually identical agent and avatar has a unique advantage of separating the human mind from the virtual body. Using this method, the current study is designed to test two hypothesised processes that elicit the phenomenon of SFE (i.e., MPE and AE), by testing the impacts of virtual social co-presence on cognitive performance. We do so by exploiting the unique societal context of government imposed self-isolating during outbreak of Covid-19 pandemic, which led to the recent boost of video-mediated online social interaction. Considering we are also testing the impacts of realistic video presence of the companion, it is important to note that both virtual character conditions (agent, avatar) are assumed to have a lesser social impact (influence) than the video-based video presence of another human, as per the threshold model of social influence (TMSI: Blascovich, 2002). According to the TMSI, the higher levels of social realism and interpersonal relevance, experienced by the participant during a live video conference with a real person, will always have a social influence advantage over a less visually meaningful virtual character's interactive presence.

In accordance with the canonical manifestation of SFE (see ***Introduction: Social Facilitation Effect***), we expect that the SFEs will manifest as better performance on RRP easy tasks (lower RT, higher accuracy) and worse performance on RRP difficult tasks (higher RT, lower accuracy) when accompanied by a companion in contrast to being alone. The significant difference between the easy and difficult RRP conditions will be analysed as part of the omnibus analysis (difficulty). The hypotheses related to predicted impacts are as follows.

Hypothesis One(H1): Mere Presence Effect (MPE). The MPE hypothesises that SFE rises due to uncertainty of companion actions within the shared environment, irrespective of who they are or whether they are actively monitoring the participant. We, therefore, predict that the MPE-related SFE will occur only when the companion is present (versus no companion present), regardless of whether they attend to the participants (non-attentive or attentive). In our manipulation, we expect MPE in all three companion type conditions (real-human, avatar, agent).

Hypothesis Two (H2): Audience Effect (AE). The AE assumes that SFE arises due to mentalizing processes relating to others' judgment of one’s performance and that these mentalizing processes only occur when the participant believes the attentive companion is capable of mentalising, i.e., real-human or avatar but not agent. Therefore, we predicted that we will only observe the SFE (AE) in the presence of an attentive companion (attentive vs non-attentive and none combined) with the capacity to mentalise, i.e., real-human or avatar but not agent.

2.3 Methods

2.3.1 Participants

Out of 90 participants tested, data from 54 adult participants (18 per between-subjects group), 44 Female (10 Male), mean age *M* = 26.94 (*SD* = 5.87), age range 19-41 years were entered into the final analysis (see reasons for participant exclusion below). Data were gathered from an opportunistic sample of university students and employed adults, self-reported as neurotypical with no clinical diagnosis in ASD (autism spectrum disorder) and Social Anxiety. The target sample size (N = 54) was estimated using G*Power, at 1-β = .8, α = .05, Cohen f = .44. The effect size was estimated from significant (Task x Audience) AE-based interaction in (Dumontheil et al., 2016). Participants who did not understand the cognitive (RRP) task or did not believe the companion type implication were excluded from the analysis (see *Participants Exclusion* below for more information). Access to a personal computer, stable internet connection, and a good lighting source at participants' homes was a formal requirement. The study was approved by Birkbeck, University of London, Ethics Committee: 192084.

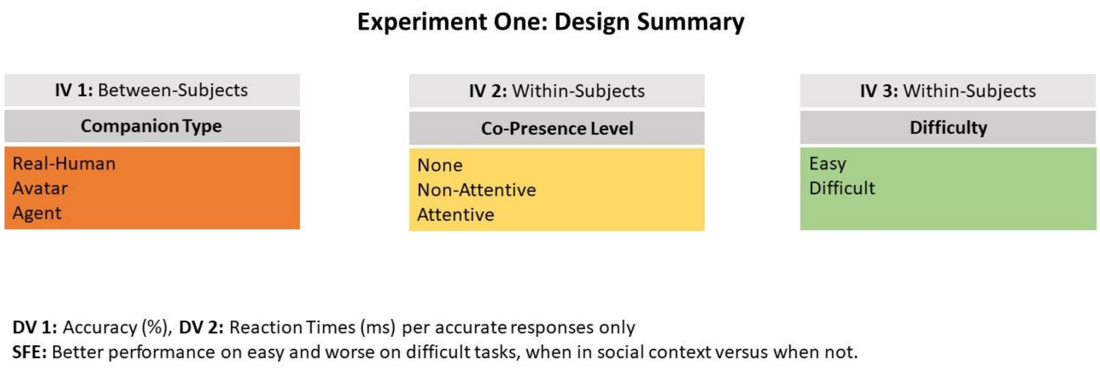
We had to test 90 participants instead of the pre-planned recruitment target of 70, due to unexpected difficulties encountered during the COVID-19 pandemic. Out of 90 participants who attended the study, 31 were excluded due to the issues related to remote in-home testing, such as technical issues (internet, camera, and computer problems) and home-based distraction (alarms, doorbells, street noise, other household residences). Out of the remaining 59 participants, 5 participants were removed for not believing the companion type manipulation (see *Participants Exclusion* below).

2.3.2 Design

As per our Registered Report (Sutskova, Senju, & Smith, 2020), we have systematically manipulated three independent factors, the companion type (*between-s;* Real-Human, Avatar, Agent), the degree of co-presence (*within-s;* none, non-attentive, attentive), and task difficulty (*within-s*; easy, difficult). Cognitive performance was measured in Reaction Times (RT, for accurate responses only) and Percent Accuracy (%) during the performance of Relational Reasoning Paradigm (RRP: (Dumontheil et al., 2016a). To reduce the possible reflexive-random responses, both per cent of accurate responses and RT were only counted for the trials which correct answer RTs are within the 99.7 percentile (3 SD, per each Difficulty condition), and over 250 ms from the stimuli onset, based on the average RT for keyboard response to visual stimulus onset (Jain et al., 2015). See **Figure 2.1** for the illustrative schematic of all the factors and their corresponding levels.

Figure 2.1

Schematic of Independent Variables and Corresponding Levels in Experiment One.



2.3.3 Participants Exclusion

After the study completion and before debriefing, all participants were asked about their subjective experience of the virtual interaction. To make sure the participants believed their companion condition (real-human, avatar, agent) the researcher asked the participant directly whether they believed the companion was either AI- or Researcher- driven. The belief response was noted down as binary YES (1) / NO (0). Participants then reported thoughts about their subjective experiences under the social co-presence conditions (attentive, non-attentive). The subjective reports were noted down alongside the participant number and the binary belief response. Only participants who believed their interaction occurred with the assigned companion, with companion performing an assigned action (non-attentive, attentive) were included in the final analysis. Uncertain or disbelieving participants were excluded.

2.3.4 Software and Stimuli

The zoom video chat messenger (zoom.us) was used so the researcher and participant could communicate remotely. screen-share was used to visually project the participant's view of the task to the researcher. An online experimental task engine (gorilla.sc) was used to enable participants access to the experimental RRP task at home. For the real-human observer, the researcher used their live video feed. for the virtual observers, the same character was used both for avatar and agent (**Figure 2.2**). the virtual character in the study was a visually modified free template illustration (Cassandra) provided by the adobe character animator (www.okaysamurai.com/puppets).

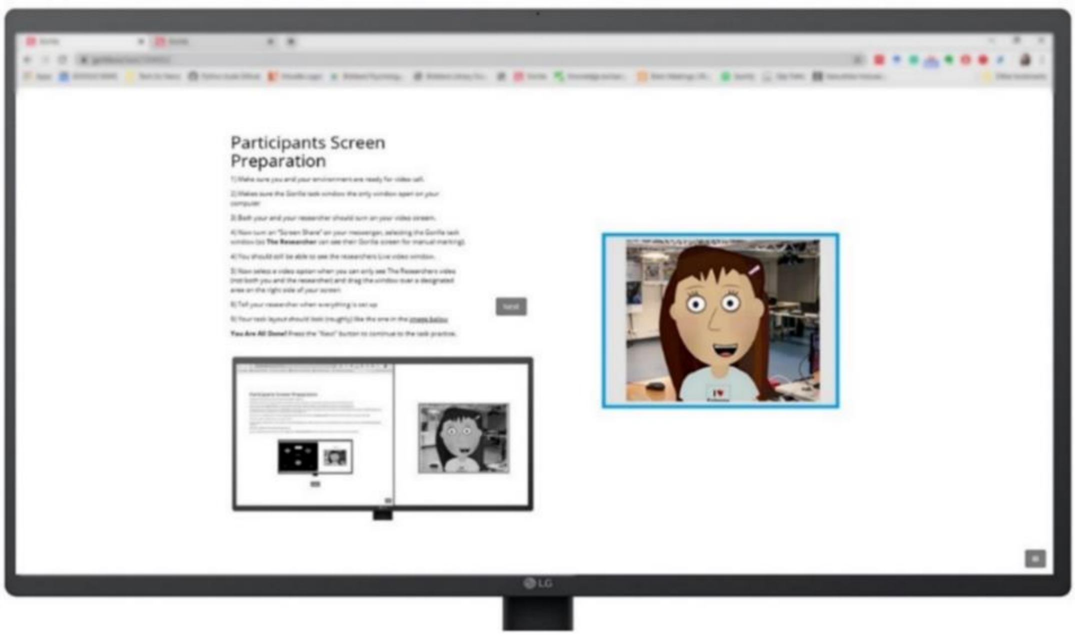
Figure 2.2

Virtual Character (Avatar or Agent) During the Marking (Attentive) Condition with Animated Interactive Eyes (left) or Turned Away (Non-Attentive During No Live Marking (right).

The character was controlled via adobe character animator software in real-time. The software tracked the researcher’s live motion and gaze-shifts through their web camera (both for agent and avatar), as well as lip-synched to the researcher’s speech (only for avatar condition). the character could look at the participant and their performance or look away. The attentive interactive eyes were used in the attentive condition when noting down participants' performance in real-time (live). In the non-attentive condition, the character was moving similarly to the attentive condition, but the character was turned away from the participant and their performance screen. In the co-presence: none condition there was no companion visually present, and the screen-sharing and participants camera was off. The companion type was introduced during the first meeting states, as the participants were setting up their screen for the experiment, see **Figure 2.3** below.

Figure 2.3

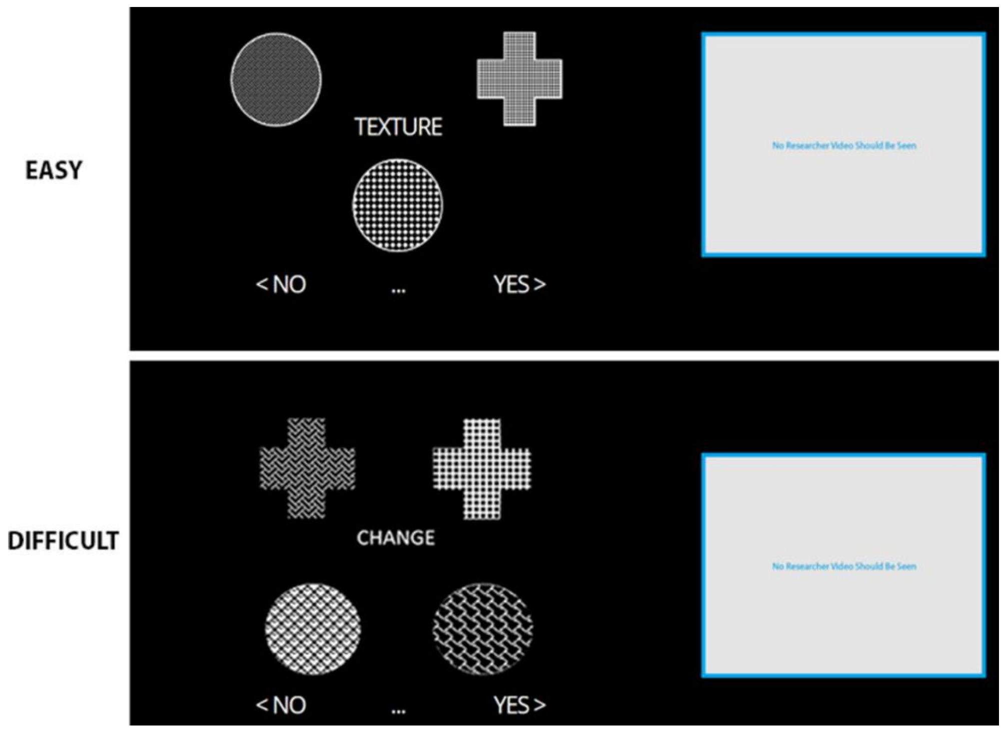
Participants View of The Preparation Screen, With Virtual Companions Video Positioned on The Right Side of The Screen.



The cognitive task used for the experiment was Relational Reasoning Paradigm (RRP), a visual pattern matching logic task, adapted from (Dumontheil et al., 2016), shown to elicit SFE. The task consisted of two difficulty levels of cognitive load, easy and difficult (visual examples in **Figure 2.4***)*. During the easy condition, the participants saw three images and were required to match either the shape or texture of the top two images to the image on the bottom. The command prior to initializing the easy trial was, either “Match Shape” or “Match Texture”. During the difficult trials the participants saw four images (two on the top row, two on the bottom) and were asked to match whether the top row two images changed in the same way as the bottom two. The change could have occurred either in shape or texture.

Figure 2.4

Participants Task View of The Co-Presence None (Easy: Top, Difficult: Bottom) Condition, With Co-Presence None View in The Window on The Right. For Attentive and Non-Attentive Conditions, The Companions Live Video Is Present.



For easy conditions the commands were always either "Match texture" or "Match Shape". For example, in **Figure 2.4**, the top illustration for easy task (EASY) shows the trial stimuli and command following the command "Match Texture". In this example, the easy task answer for the trial should be left arrow click representing "NO", meaning none of the top images match the bottom image in texture. This is because, although one of the top images matches the bottom row image in shape (circle), neither of the textures of the top row images matches the bottom image in texture. For difficult condition, the task command was always "Match Change". Similarly, to easy task, the participant had to click left arrow key for "NO", if the top and bottom images do not change in the same way, from left top image to the right top image. The participants clicked the right arrow key for "YES", if the two top images change in the same dimension (either in shape or texture) from left top image to the right top image, as do the bottom left to right images. The type of shape or texture in which the top and bottom row changes does not matter for the difficult condition, only whether the rows change in shape or texture. For example, the **Figure 2.4** bottom illustration (DIFFICULT) for the difficult task demonstrates an onscreen stimuli and command following the command "Match Change". In this example, the top row two images change in dimension of texture, but not shape, i.e., both two top row images are a plus sign with different textures. The bottom row two images also change in texture but not in shape, i.e., both bottom row images are circles with different textures. Therefore, considering both the top and bottom row images change in the same way, in texture but not shape, the current difficult trial answer will be a right arrow click "YES" the change matches. As the participants perform the easy and difficult tasks the commands are randomised and counterbalanced. The images always change only in one dimension texture or shape.

There were 40 Easy and Difficult randomised trials per each of the three condition blocks, 120 trials in total. Participants used left and right keyboard presses to respond to the task presented for a maximum of 3.5 seconds per trial.

Participants' personal computers (laptops) needed to be equipped with a working web camera and a keyboard to test participants from their own homes. The experiment was screen-captured.

2.3.5 Conditions and Social Deception

To avoid any confounds based on participants' guessing the experimental manipulation, minimal social deception was made (ethical approval granted). The participants were told a cover story that we were piloting a new online-testing-software that can track participants performance based on messenger screen-share data and predict whether their responses were going to be correct or not based on their webcam-based eye-gaze. Participants were told that they would be informed when marking (pen icon: attentive observer) and no marking sessions occur (crossover pen icon: non-attentive observer) via on-screen notification icons. Please see the on-screen instructions and the study conditions pipeline on our OSF project page: https://osf.io/d5ers.

Co-presence conditions (within-subjects): none, attentive, non-attentive, conditions were counterbalanced, with co-presence none being either first or last condition, and non-attentive and attentive conditions randomised.

For the attentive condition, participants were told that their virtually co-present companion would be manually marking their performance for future quality control of the automated online-testing-software. In the non-attentive condition, participants were told that their companion would be visually present but not attending to their task. In the co-presence none condition, the participants were told the researcher needed to set up software; therefore, all media sharing needed to be switched off (no camera or screen-share). Participants performed the task alone and told the researcher through the microphone when they finish.

Companion Type conditions (between-subjects): participants were randomly assigned to real-human, avatar, or agent groups.

The real-human companion group performed next to a live video of the researcher marking down participants performance through screen-share during attentive condition. the researcher was looking away from the participant during non-attentive conditions, busy working on other tasks.

The avatar was controlled by the researcher to pay attention to participants answers during the attentive condition, providing natural character motion and eye gaze shifts based on researchers' natural gaze during the non-attentive condition, the motion of the character was present and based on the researchers' natural motion. However, in contrast to the attentive condition, the avatar was turned away from the participant showing the participant its back (see **Figure 2.2**). The participants were told that when the researcher does not face their laptop camera, the avatar is programmed to turn around, avoiding participants belief that monitoring occurs during non-attentive conditions.

In the agent condition, the character was controlled by the researcher in the same way as for the avatar condition. The participants were instructed that the agent was controlled by an in-house AI algorithm designed to mark user performances remotely using live on-screen data. The participants were told that at one point, the algorithm will access their screen-share and video data to make predictions about their performance (attentive), and other times the program will just run in the background without analysing their performance in real-time (non-attentive). The AI-agent was told to be pre-programmed to show active-gaze reflecting what they read from screen-share and video data. Therefore, participants assumed that when the AI live data marking occurs (attentive) the agent will be actively monitoring and when the data marking does not occur (non-attentive) the agent turns away.

Emergency communication was always kept through the audio channel (no lip sync for agent condition). the instructions throughout the experiment were delivered by onscreen text instructions for all conditions.

2.3.6 Procedure

All participants logged in to the browser-based experimental software (Gorilla.sc) and followed task-screen and messenger preparation instructions. Please see our OSF page infographic for the illustration of the study sequence pipeline: https://osf.io/d5ers. During setup, the participant activated Zoom.sc messenger screen-share, so the researcher would see their task screen. All the participants had to position the researcher's messenger video window within a designated region on the right side of the screen (**Figure 2.3**). Participants were told that the video screen positioning is a requirement for consistency between participants experimental layouts. The researcher highlighted that this layout requirement made sure that the researcher's video screen would not interfere with the main task region and stimuli. The participants were told that for all conditions their gaze and performance data is recorded for further later anonymised analysis. During the debriefing, the participants were told that we have recorded their full videos throughout the study and were given a chance to withdraw their video data from further analysis. All experimental sessions ended with a series of individual difference trait questionnaires.

After the experimental setup confirmation from the participant, the researcher introduced the cognitive task RRP, at both easy and difficult levels, with a short practice (5 trials each, ensuring task understanding) and a questions session. Practice session followed with gaze calibration and then the experimental task, starting either with co-presence none condition (see **Figure 2.4** for participant view of the condition) or either attentive or non-attentive conditions in which there was a type of co-presence with the companion.

Whilst exposed to the companion, the participants perform the RRP task responding to the commands, by pressing left arrow for "NO" response and right arrow for "YES". If participants answer is correct, the screen responded with "correct" if the answer was incorrect the screen response was "incorrect".

2.3.7 Analysis Plan

This analysis plan was preregistered at the OSF page (Sutskova, Senju & Smith., 2020), as part of the registered report published in the Journal of

Technology, Mind & Behavior (Sutskova, Senju & Smith., 2022). The minor deviations of the current **Analysis Plan** from the original on the OSF page are related to renaming of the factors for purpose of this thesis only.

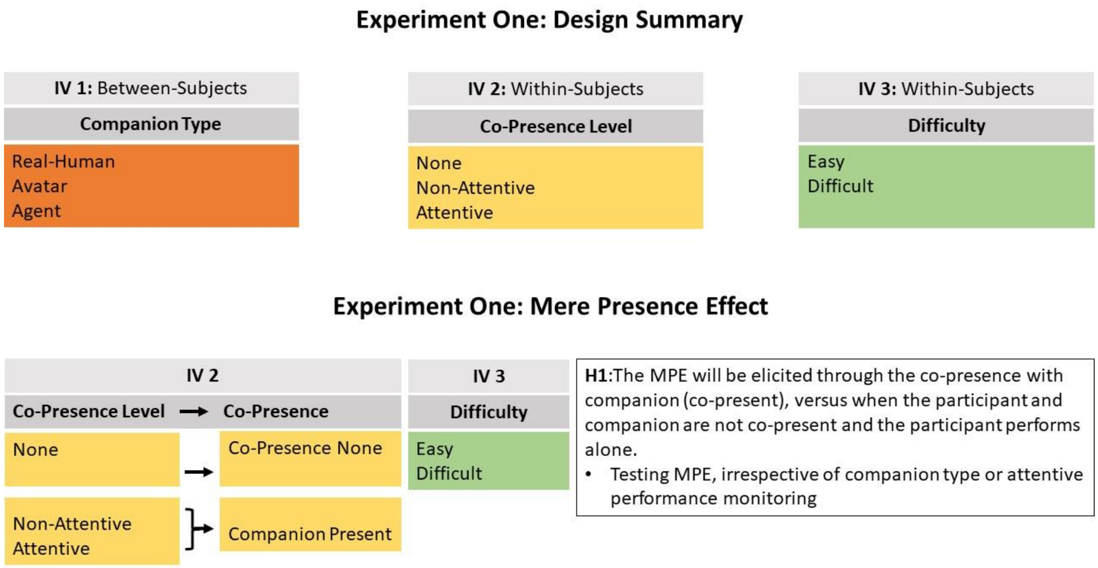
Two separate ANOVAs with the three independent factors above were carried out to investigate RT and Accuracy. Simple effect analyses followed up the ANOVA to assess *a priori* planned predictions of Hypotheses as specified below. These ANOVAs were then be followed up with a series of planned contrast, to examine the direction of effects within each level of Difficulty based on the expectation from SFE. The specific contrasts for each hypothesis are described below.

Hypothesis One (H1), MPE: would be supported by the presence of significant co-presence x difficulty interaction. See **Figure 2.5** for the illustrative schematic of factor mapping in analysis.

Hypothesis 1 predicted a main effect of co-presence for each level of difficulty, expected from SFE. According to SFE, in the easy task, the co-presence none condition should show 'worse' performance (i.e., lower accuracy and slower RT) than the companion present condition (a combination of non-attentive and attentive conditions). In the difficult task, the co-presence none condition should show 'better' performance (i.e., higher accuracy and faster RT) than non-attentive and attentive conditions. *A priori* contrasts were conducted between co-presence: none conditions versus the combination of non-attentive and attentive companion conditions, which were conducted separately at each difficulty level (easy, difficult).

Figure 2.5

Schematic of Independent Variable Mapping onto the MPE Analysis in Experiment One



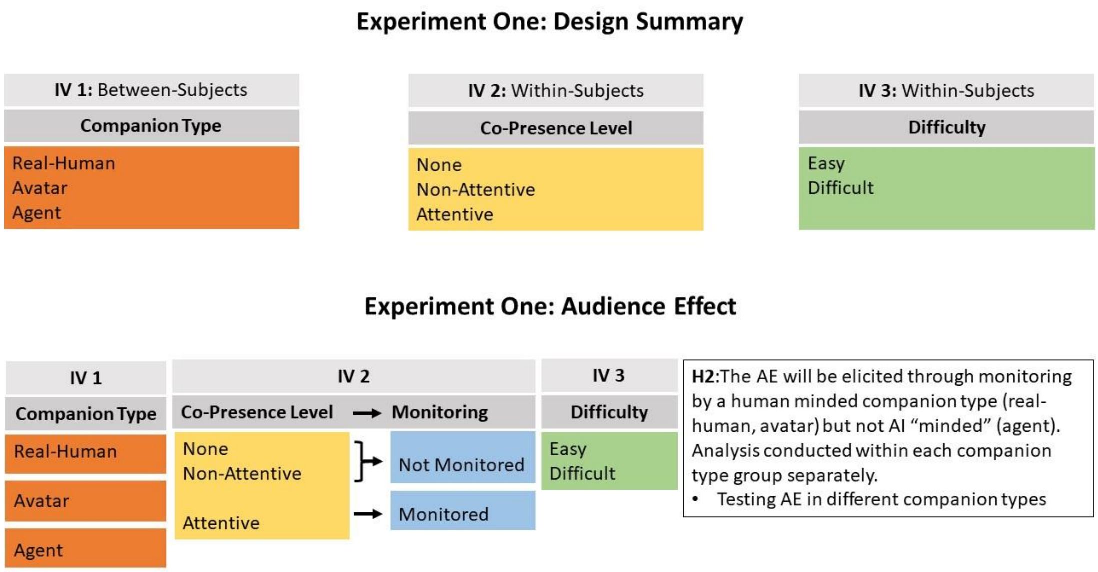
Hypothesis Two (H2), AE: would be supported by the presence of significant co-presence x companion type x difficulty interaction. See **Figure 2.6** for the illustrative schematic of factor mapping in analysis.

The follow-up analysis for the three-way interaction consisted of planned contrasts within difficulty x co-presence interaction, for each companion type group separately. The planned contrast compared performance changes within each of the difficulty levels (easy, difficult), comparing attentive versus the not monitored condition (a combination of co-presence none and non-attentive companion conditions). In the easy task, the attentive condition should show 'better' performance (i.e., higher accuracy and faster RT) than non-attentive and co-presence: none conditions combined (not monitored). In the difficult task, the attentive condition should show 'worse' performance (i.e., lower accuracy and slower RT) than non-attentive and co-presence: none conditions (not monitored). We expected these results to be significant in real-human and avatar groups, but not in the agent group. The Bayesian analysis will be used to test support for the null effect in companion type groups.

Exploratory Bonferroni corrected post-hoc comparisons will be conducted to investigate further effects, such as the differences in the magnitude of SFE's between all three companion type conditions.

Figure 2.6

Schematic of Independent Variable Mapping onto the AE Analysis in Experiment One



2.4 Results

Participants with an accuracy less than 3 SD (99.7 %) below the sample mean and under 250 ms in average reaction times (RT), were excluded from the analysis. Only participants who firmly confirmed belief in the manipulation (see *Participants Exclusion* in Methods) were included in the final analysis. As per *Analysis Plan*, the statistical analyses were run on $N = 54$ participants, with 18 participants per each companion type group.

Sphericity of data was confirmed ($p > .05$) between and within the conditions of interest both for accuracy and RT. The Levene's test showed a slight homogeneity deviation in accuracy between the companion type conditions for non-attentive difficulty, $p = .023$, for RT homogeneity was asserted ($p > .05$). The summary of means and standard errors for all the conditions and corresponding levels are presented in the table below **Table 2.1** for percent accuracy and **Table 2.2** for reaction times.

Table 2.1

The Means (M) And Standard Errors (SE) Of Percent Accuracy (%) All the Levels By Each Factor Within The Experiment One Design.

Conspecific Type	Co-Presence	Difficulty	*M*	*SE*
Real-Human	Attentive	Easy	90.56	2.13
		Difficult	78.61	4.02
	Non-Attentive	Easy	90.00	1.55
		Difficult	73.89	3.18
	None	Easy	88.33	1.92
		Difficult	71.11	3.46
Avatar	Attentive	Easy	90.56	2.13
		Difficult	80.56	4.02
	Non-Attentive	Easy	95.00	1.55
		Difficult	82.22	3.18
	None	Easy	94.17	1.92
		Difficult	77.78	3.46
Agent	Attentive	Easy	92.78	2.13
		Difficult	86.39	4.02
	Non-Attentive	Easy	94.17	1.55
		Difficult	90.56	3.18
	None	Easy	93.89	1.92
		Difficult	83.89	3.46

Table 2.2

The Means (M) And Standard Errors (SE) Of Reaction Times (RT) For All the Levels by Each Factor Within The Experiment Two Design.

Conspecific Type	Co-Presence	Difficulty	*M*	*SE*
Real-Human	Attentive	Easy	1511.065	72.573
		Difficult	2020.955	102.656
	Non-Attentive	Easy	1593.640	76.845
		Difficult	2034.285	111.640
	None	Easy	1535.150	70.408
		Difficult	2112.250	113.033
Avatar	Attentive	Easy	1269.012	72.573
		Difficult	1854.190	102.656
	Non-Attentive	Easy	1399.513	76.845
		Difficult	1800.088	111.640
	None	Easy	1387.630	70.408
		Difficult	1934.637	113.033
Agent	Attentive	Easy	1291.230	72.573
		Difficult	1766.641	102.656
	Non-Attentive	Easy	1261.163	76.845
		Difficult	1780.342	111.640
	None	Easy	1317.861	70.408
		Difficult	1865.943	113.033

Two Mixed Three-Way ANOVA's, 3 companion type x 3 co-presence x 2 difficulty, were conducted on the accuracy (%) and RT (ms) separately, followed up by planned analyses (see ***Analysis Plan*** *above*). The main body of the ***Results*** section focuses on reporting the outcomes of the hypothesised effects (MPE, AE and companion context effects) and any additional significant results that were not originally predicted.

2.4.1 Difficulty

Before testing the hypotheses presented above, we investigated the main effects of difficulty to confirm that RRP task difficulty levels employ different levels of cognitive effort (i.e., difficult tasks were indeed more 'difficult' than east tasks), which is prerequisite of the RRP. A three-way ANOVA indeed indicated a significant main effect of difficulty, both for Accuracy and RT in accordance with expectations of the RRP task, with expected direction. The performance on the easy condition was more accurate and faster than those on the difficult condition: accuracy, $F(1, 51) = 48.85$, $p < .001$, $\eta_p^2 = 0.49$ (easy: $M = 92.2$, $SD = 6.2$ .00, difficult: $M = 80.60$, $SD = 14.0$), and RT $F(1, 51) = 148.66$, $p < .001$, $\eta_p^2 = 0.75$ (easy: $M = 1396.25$, $SD = 291.37$, difficult: $M = 1907.7$, $SD = 422.87$).

2.4.2 Mere Presence Effects (MPE)

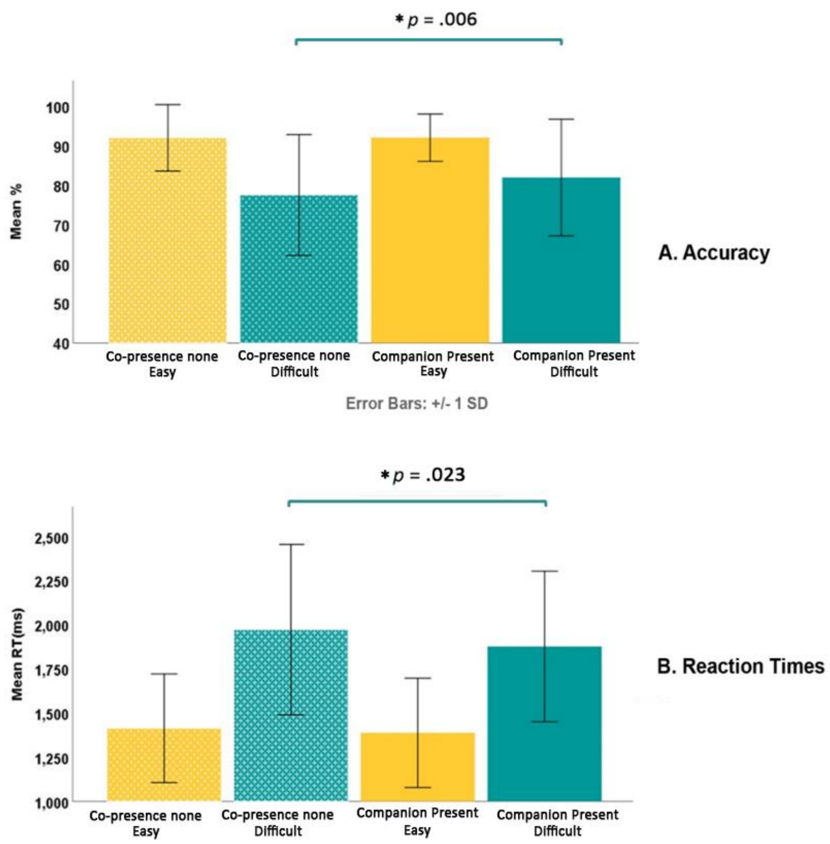
For the MPE hypothesis, we predicted that the three-way ANOVA analysis would indicate a significant two-way co-presence x difficulty interaction. In percent accuracy, there was a significant co-presence x difficulty interaction as predicted, $F(2, 51) = 3.181$, $p = .047$, $\eta_p^2 = .059$. The planned follow up comparisons, between the co-presence none and companion present conditions (the non-attentive and attentive companion conditions combined), revealed that the performance accuracy for the difficult task was significantly higher in the companion present conditions ($M = 82.04$, $SD = 14.82$) in contrast to co-presence: none conditions ($M = 77.60$, $SD = 15.35$), $t(1, 53) = 2.85$, $p = .006$. Note that the direction of the effect was opposite to our hypothesis (***H1***), which predicted that the performance in the difficult condition would decrease (and would increase in easy condition) in the presence of a companion. There were no significant differences for the easy conditions $t(1, 53) = 0.051$, $p = .96$, between the companion present conditions ($M = 92.18$, $SD = 6.0$) and co-presence none ($M = 92.13$, $SD = 8.45$) conditions.

For RT, there was no significant MPE related co-presence x difficulty interaction, in contrary to prediction, F (2, 51) = 2.31, p =.104, η_p^2= 0.043. The planned follow up comparisons (see **Analysis Plan**) between the co-presence none condition versus companion present conditions, revealed that similarly to accuracy, the RT for the difficult task indicated significantly better(faster) performance, t(1, 53) = 2.35, p = .023**,** during the online companion present (M = 1876.08, SD = 425.93) in contrast to co-presence none condition (M = 1970.94, SD = 481.94). Again, the direction of results was opposite our hypothesis one (***H1***) prediction, which predicted that performance in the difficult condition would decrease (and would increase in easy condition) in the companion present (MPE) condition. For the easy conditions, there were no significant difference between companion present (M = 1387.60, SD = 309.10) and co-presence: none conditions (M= 1413.55, SD = 306.96), t (1, 53) = 0.89, p = .38.

The co-presence x difficulty interaction in both Accuracy and RT indicates significant performance improvement on the difficult, but not easy tasks, when performing alongside an online companion in contrast to performance alone (**Figure 2.7**). Although it is in line with ***H1*** that mere presence of others influences task performance, the results did not support the directional prediction derived from the canonical SFE literature, that during companion present conditions, the performance will decrease in difficult condition and increase in easy condition, when compared to the performance in co-presence: none conditions.

Figure 2.7

Mere Presence Effect Planned Contrast Descriptive Statistics (M,1 SD) for Accuracy (A) And Reaction Times (RT) (B).



Note: There is a significant increase in difficult performance in companion present conditions in contrast to none co-presence. The increase is present in both accuracy (a) and RT(b), ** $p < .01$, * $p < .05$ respectively. No SFE idiosyncratic interaction is present.

2.4.3 Audience Effect (AE)

For the AE related hypotheses, we predicted a significant three-way co-presence x companion type x difficulty interaction, with a set of co-presence x difficulty planned contrasts to be conducted within each companion type group.

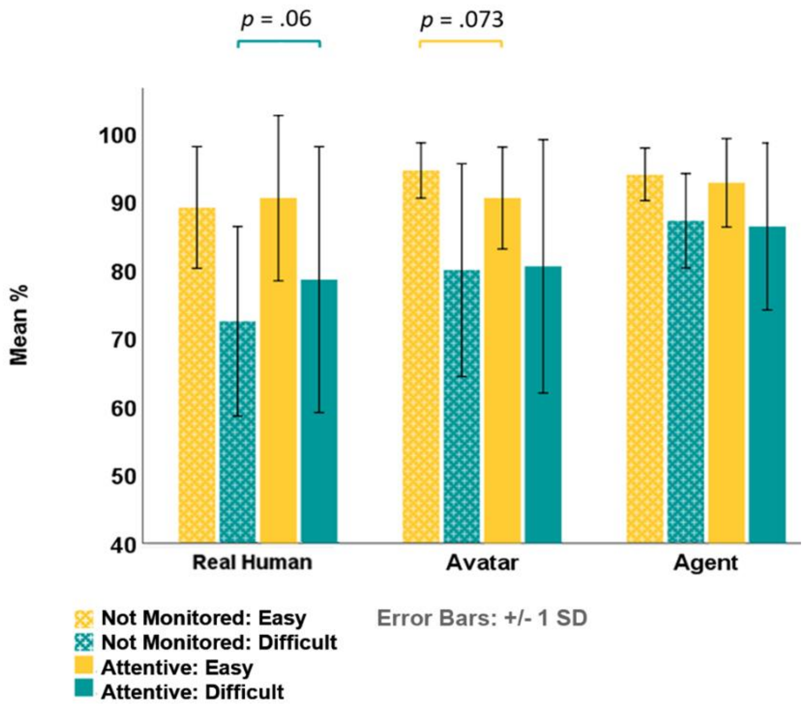
There was no significant three-way co-presence x companion type x difficulty interaction, neither for Accuracy F (4, 53) = 0.572, p = .68, η_p^2 = 0.022, nor for RT F(4, 51) = 0.97, p = .43**,** η_p^2 = 0.037, which did not support our hypothesis.

A planned AE comparison was performed within each companion type group, comparing attentive companion (when the observer is marking) versus not monitored (co-presence none and non-attentive companion combined) conditions. We predicted that the AE, i.e., worse accuracy in difficult conditions, and better accuracy in easy conditions, in the attentive companion condition compared to conditions in which participants were not monitored, will emerge only in the real-human and avatar conditions, but not in agent condition. For performance accuracy there was no significant co-presence x difficulty interaction within either of the companion type groups, real-human, F(1, 17) = 1.67, p = .21, η_p^2 = 0.09, avatar, F(1, 17) = 2.96, p = .10, η_p^2 = .15, or agent F(1, 17) = 0.025, p = .88 , η_p^2 < 0.001, which did not support our hypothesis.

Planned comparisons for accuracy indicated that participants in real-human and avatar conditions showed marginal performance change between attentive companion and not monitored conditions (**Figure 2.8**). The real-human attentive monitoring marginally increased participants performance only in difficult condition (*M = 78.61, SD = 19.46)* in contrast to not monitored difficult condition (*M = 72.50, SD = 13.88)*, t (1, 17) = 2.024, *p = .06*. In avatar condition attentive monitoring decreased performance only on easy condition, with easy condition being marginally worse under attentive companion (*M* = 90.56*, SD* = 7.45) than when not monitored *(M* = 94.58*, SD* = 4.04*), t* (1, 17) = *1.91, p = .073*. However, none of these effects reached significance, and directions of non-significant effect were not consistent with each other. As predicted, there was no significant change in agent groups (see **Appendix A** for the breakdown of AE *t*-tests).

Figure 2.8

Audience Effect Planned Contrast Descriptive Statistics (M, 1 SD) For Performance Accuracy.



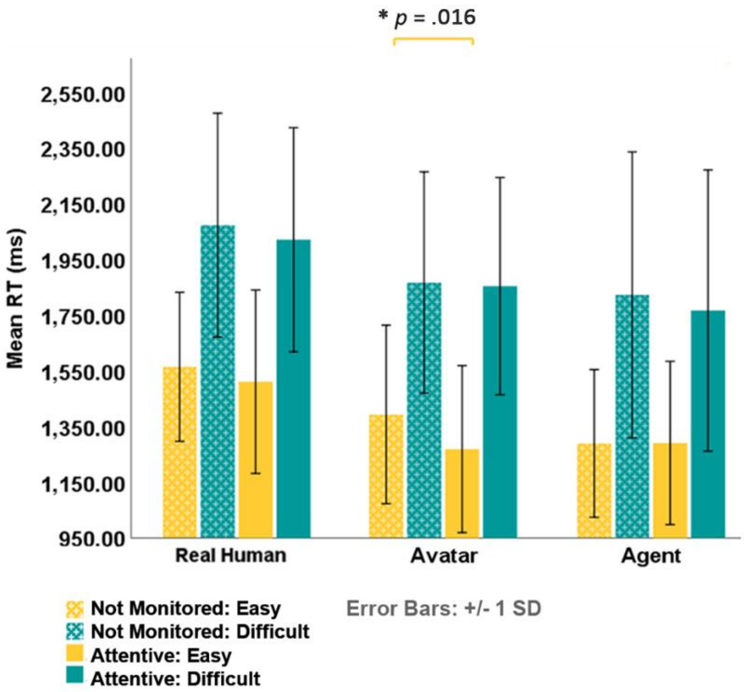
Note: A marginal change in the performance in Real-Human and Avatar observer groups. The change however does not follow the SFE idiosyncratic interaction.

For performance RT, there were no significant co-presence x difficulty interaction within either of the companion type groups, real-human, $F(1, 17) < .001$, $p > .99$, $\eta_p^2 < 0.001$, avatar, $F(1, 17) = 2.88$, $p = .11$, $\eta_p^2 = .145$, or agent $F(1, 17) = 0.58$, $p = .46$, $\eta_p^2 < 0.033$.

Planned contrasts indicated that only avatar group showed significant increase on the easy condition between attentive companion (*M* = 1269.01, *SD* = 299.76) and not monitored (*M* = 1393.57, *SD* = 320.62) conditions, $t(1, 17) = 2.68$, $p = .016$ (see **Figure 2.9**), there were no significant difference in real-human and agent groups (see **Appendix A** for breakdown of AE *t*-tests).

Figure 2. 9

Audience Effect Planned Contrast Descriptive Statistics (M, 1 SD) For Performance Reaction Times (RT).



Note: A significantly faster performance on easy task in Avatar observer group when monitored versus not monitored. No other companion type group's performance change reached statistical significance. The significant change observed did not follow the SFE idiosyncratic interaction. * $p < .05$.

Overall ***H2*** was not supported from our results, with no predicted three-way interaction between co-presence x companion type x difficulty or co-presence x difficulty interaction in real-human or avatar condition. However, there was weak support for a broader AE effect, that real-human and avatar, but not agent, conditions show a trend that performance in attentive condition is different from when participants were not monitored (co-presence none and non-attentive combined). Note that these effects only reached significance in one condition in RT and approached significance in two conditions in accuracy. These directions of results were however not in line with our directional prediction derived from the canonical SFE literature, which would predict worse performance in difficult trials and better performance in easy trials during attentive observer, versus when not monitored by the companion (AE).

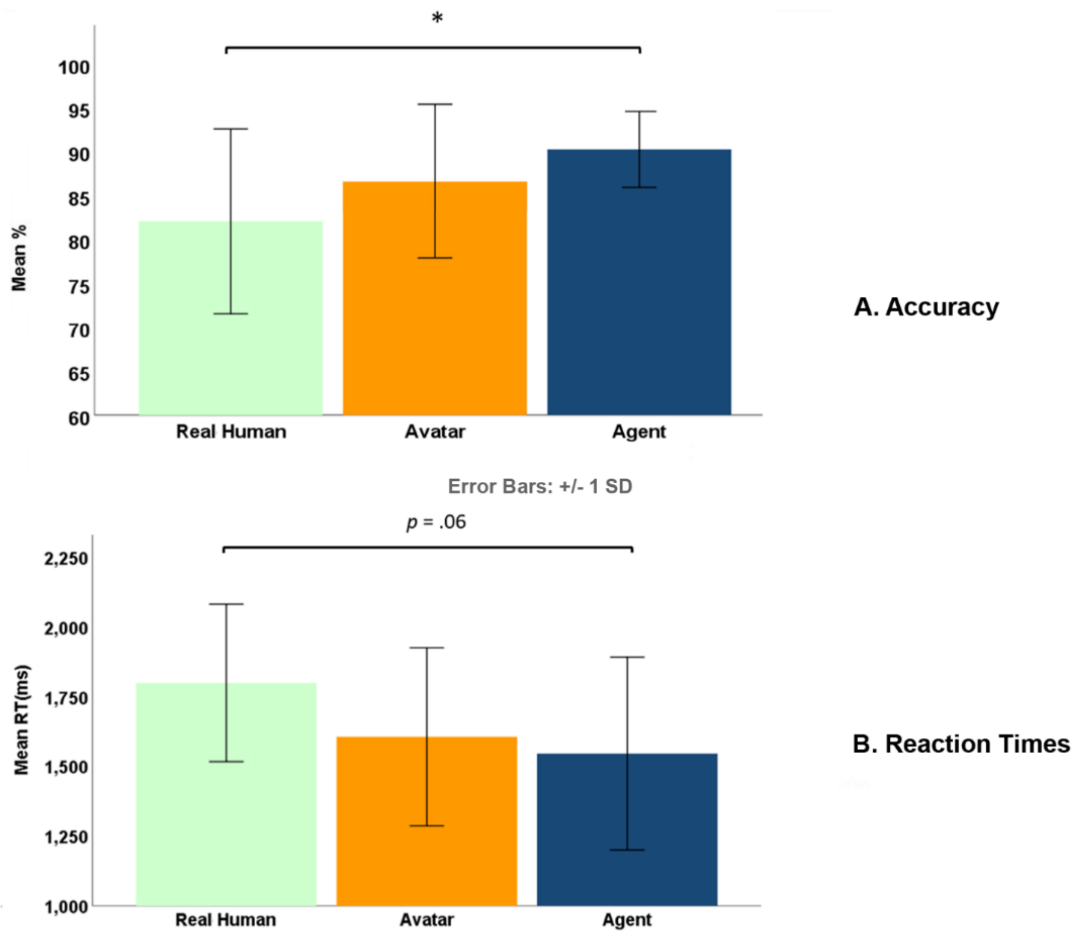
2.4.4 Social Context Effect

A three-way ANOVA revealed a significant main effect of companion type group, both in accuracy F (2. 51) = 4.40, p = .017, η_p^2 = 0.147 and in RT F (2. 51) = 3.14, p = .052, η_p^2 = 0.11. There was a linear increase in performance with decreasing 'humanness' (a linear trend for accuracy, p = .005; and RT, p = .02), between the companion type groups, with real-human groups performing overall worst, followed by avatar, and the best performance is in the agent group.

The proposed follow up contrasts (3 pairwise, Bonferroni corrected, see *Analysis Plan*) between the three companion type groups in accuracy, indicated a significant difference between real-human and agent groups, p = 0.014, with no significant difference between agent and avatar (p = .61), or avatar and real-human groups (p = .3), see **Figure 2.10, a**. The RT indicated a similar trend, with a marginal but non-significant difference between real-human and agent (p = .06), and no significant differences between avatar and agent p > .99, or real-human and avatar groups (p = .22), see **Figure 2.10, b**.

Figure 2.10

The Effects of Companion Type (M, 1 SD) On Accuracy (A) And Reaction Times (RT).



Note. A gradual improvement in performance as social influence decreases, a) Accuracy, b) RT. * p = < 0.05.

2.4.5 Monitoring and Co-Presence

A three-way ANOVA revealed a significant main effect of co-presence in accuracy F (2, 51) = 3.39, p =.037, η_p^2 = .062, and a marginal effect for RT F (2, 51) = 2.47, p = .090, η_p^2 = .046.

Post-hoc exploratory comparisons (Bonferroni corrected, 3 pairwise test) of a significant co-presence type effect in accuracy indicated a significant quadratic (p = .038), but not a linear trend (*p = .128)*, of performance change with the increase in attentive presence, in direction from co-presence none to non-attentive then to attentive companion (see **Appendix B** for breakdown of conditions). Non-attentive co-presence (*M* = 87.64, *SD* = 8.84) has significantly improved accuracy of performance versus co-presence none condition (*M* = 84.87, *SD* = 10.2), p = .015, with no significant difference between co-presence none and attentive companion (*M* = 86.57, *SD* = 10.77), p = .128, and non-attentive and attentive companion (p = .36).

Post-hoc exploratory contrasts (Bonferroni corrected, 3 pairwise test) for marginal main effect in RT revealed a significant linear (p = .019), but not quadratic (p = .74) trend of performance change with the increase in attentive presence, with the slowest performance in co-presence none(*M* = 1692.24, *SD* = 352.23), followed by non-attentive (*M* = 1644.84, *SD* = 382.37), and fastest performance in attentive companion conditions (*M* = 1618.85, *SD* = 340.02). There was a borderline significant performance difference between co-presence none and attentive companion, p = .056, and no significant difference between co-presence none and non-attentive (p = .56), and non-attentive and attentive companion ($p > .99$).

2.5 Discussion

The current experiment tested whether the phenomenon of the social facilitation effect (SFE), often reported in physical real-world, also impacts cognitive performance during the increasingly common scenario of an online video meeting. Participants were asked to perform a quick-response visual logical reasoning task (relational reasoning paradigm – RRP(Dumontheil et al., 2016a), under different levels of confederate presence during an online video meeting. We compared how the perceived social agency of the online other (companion) impacted participant performance at different levels of social presence and attentiveness. The social impact was predicted using the threshold model of social influence (Blascovich, 2002). Participants had an online video interaction with one of the three different levels of companion's co-presence: highest being in a call with a confederate (real-human: a realistic visual human presence), the middle being in call with a visually less realistic human-controlled animated avatar (implied human presence), and lowest being in a call with an AI-algorithm controlled animated Agent (implied non-human minded presence). The social impact was tested based on the predictions derived from the theories on two processes eliciting the phenomenon of SFE, Mere Presence Effect (MPE: Rajecki et al., 1977) and Audience Effect (AE: Wolf et al., 2015).

Our results showed that during an online video meeting the mere presence alongside a virtual companion significantly altered performance on more difficult tasks, with performance becoming more accurate and quicker. The performance was not significantly affected by whether participants believed their performance was monitored nor by the type of companion present. It was affected by the shared mutual video presence (co-presence). Although our findings support the prediction of performance change in co-presence of a virtual online companion versus performing alone, the results did not support the predicted direction of our first hypothesis: SFE would manifest as an increase in performance for easy and a decrease in performance for difficult trials.

For the AE, we hypothesised that the participants' belief in being attentively monitored would change their cognitive performance according to the SFE. Unlike the MPE, which we postulated was subserved by more primitive cognitive mechanisms, AE was hypothesised to be subserved by mentalising. Therefore, we predicted the engagement of AE on the manifestation of SFE in the presence of a human mind (real- human and avatar), but not in the presence of non-human companion (AI-agent). Our results were numerically and broadly in line with our prediction that participant performance would change during attentive monitoring by the human-mind companions, but not in the agent group. However, the finding did not reach statistical significance, showed an inconsistent effect, and was not in the predicted direction from the canonical SFE literature. Given the unexpected directions of results for AE within the real-human video and avatar condition, any firm conclusions on the hypotheses derived from AE cannot be drawn in this chapter. The AE and MPE will be broken down to smaller impact components and the impact factors relating to these components will be explored in more depth in experiment two in the next chapter (**Chapter 3).** Specifically testing the relationship between the level of self or companion attentive and non-attentive presence, investigating possible inhibitory (distracting) and facilitator (motivating) drivers.

Alongside our main effects of interests, additional evidence on the social impact of different types of companions can be derived from our planned exploratory analyses between the companion type groups. Our results showed a gradual overall decrease in accuracy and speed of performance as the level of ‘humanness’ of companion increased. The real-human groups performed worst, followed by avatar, and with the best performance in agent groups. A similar social influence linear (gradient) trend was reported in the study looking into effects of social support contrasting real-human, avatar and agent, reporting most beneficial social support impacts in human, then avatar, and least in agent condition (Kothgassner et al., 2019). These social context effects, irrespective of co-presence level type, is in line with the phenomenon mentioned in the Introduction chapter of this thesis, the theory of planned behaviour (Ajzen, 2011) and anticipation anxiety prior to evaluation (Groupe & Nitschke, 2013), termed in this thesis evaluation anticipation. The theory of planned behaviour stating that people adjust their behaviour and expectations depending on their beliefs about the context they are planning to engage with (Ajzen, 2011). And the anticipation anxiety suggesting that people’s arousal levels heighten in the anticipation of an evaluative event (Groupe & Nitschke, 2013). The higher levels of stress arousal impacting the baseline performance outcomes (Angelidis et al., 2019). In the current our experiment, the instructions at the beginning of the study stated the social interaction context, under which the participant should anticipate performing (either real-human, avatar, or agent). Considering that participants did not know at which stage the observation will happen (randomised blocks) there is also a possible evaluation-anticipation effect relating to the companion type. In our study, the evaluation-anticipation in a more socially influential (real-human) context may have prompted more anticipatory evaluation-stress than the AI Agent mediated (low social impact) condition. Indeed, some findings suggest that the cortisol-response peaks both during anticipatory and reactive social evaluation stresses (Engert et al., 2013), especially during upcoming social cognitive (mental) evaluation (Dickerson & Kemeny, 2004). In the real-world settings, the higher levels of cognitive evaluations stress have been reported to have detrimental effects (at least acutely) on both cognitive performance (Angelidis et al., 2019), IQ-test battery (Elliot et al., 2011) and academic test performance (Cassady & Johnson, 2002). Our study shows that these impacts possibly generalise to online video social context and explain why the real-human condition was affected the most.

In addition to our main predicted effects, the results also showed the main effect of co-presence type overall. In contrast to performance when alone (co-presence none), participants performed significantly faster when attentively monitored (linear trend as monitoring level increases), but more accurately when the virtual companion was co-present but not attending to their performance (quadratic trend). This is an interesting finding in itself, as accuracy and speed of performance might vary based on the type of co-presence. The knowledge that performance is being marked (in the attentive condition) might push participants to show off better performance (increasing the speed of the task), which could have led to a speed-accuracy trade-off, leading to the observed quadratic trend in performance accuracy. Future studies should consider inverse efficiency analysis to confirm this notion of speed accuracy trade-offs. On the other hand, additional excitation relating to video co-presence, without the requirement of performative action, might create relevant arousal for focused attention without performative distraction. Therefore, the level of perceived co-presence type itself, regardless of the perceived level of task difficulties, could change the task performance of the participants. As this finding is exploratory, our speculations would merit further research.

Considering our findings, we can conclude that sharing an online video call with others impacts cognitive performance on a co-occurring task. At least for a limited duration (4 minutes per condition block), the participants' performance was enhanced when they performed more difficult tasks in the mere co-presence of an online companion, irrespective of their belief of whether the task is being attended by their online video companion or not. Additionally, our results were consistent with the claim that when participants believe their performance is monitored, the social influence of human-minded video companions (real-human, avatar) but not by AI-driven character(agent) impact participants performance differently. However, the findings within the human-minded (mentalising groups) were not significant according to our AE predictions. Whilst the AE in real-human video groups marginally facilitated the difficult task, as did all the companion groups during a significant MPE, the avatar group, although performing marginally faster, had a significant detrimental accuracy effect, but only on the easy task. The effect of the avatar was unexpected, yet interesting, therefore, to make any further conclusions, the real-human and avatar impact differences and why these differences occur require a more in-depth investigation. The next chapter will test the possible assumptions behind the effects of avatars monitoring presence on participants' performance, focusing on the self- and companion presence levels as possible drivers of performance facilitation and inhibition.

Chapter 3: Experiment Two

Deconstructing the Cognitive Impacts of Videoconferencing with an Avatar Companion

Deconstructing the Cognitive Impacts of Videoconferencing with an Avatar Companion

3.1 Preregistration

The experimental parameters, predictions and data clean up procedure relating to this chapter have been preregistered on an Open Science Framework (OSF). The details were preregistered on the OSF in January 2022, prior to the data acquisition and analysis: https://osf.io/UQVYR.

I would like to thank our then placement student Ella Edwards for her time and attention to detail when testing the participants in the current study.

3.2 Introduction

Propelled by the pandemic, the new social reality became more virtual. The communication between people became more virtually salient using augmented reality filters which modify both the appearance of the real-world environments and self-image through avatars and face filters (Miao et al., 2022; Wiggers, 2018). However, as social media companies introduce people to their virtually augmented selves, it is important to learn how we perceive the others behind their avatar masks. The current experiment tests how performing during video co-presence and the monitoring gaze of an avatar companion changes the participant's performance during real-time interaction. Importantly, this paradigm focuses on how the level of companion visual presence, through video, and levels of self-exposure, through video and performance sharing, can influence performance outcomes during performance alongside the avatar companion. To maintain consistency between the experiment one and the current experiment, the cognitive task used in the current study is relational reasoning paradigm (RRP), identical to the stimuli used in the experiment one.

In the current study, the monitoring (AE-m) by the avatar will be tested on two levels. The AE will be tested by turning participants performance screen sharing on or off. Firstly, the experiment will test the screen sharing as an independent contributing factor to AE, irrespective of whether the companion or participant are visually seen or not. Then the additive effect of performance monitoring whilst being video present will be explored as a separate analysis, see prediction below in **3.1.5. Experimental Design and Hypotheses.** The video co-presence (MPE-m) in this study represents being video co-present with the virtual companion, irrespective of whether the companion is explicitly monitoring the participants performance. We will test the social impact of video co-presence at three levels. The first factor of co-presence is participants self-visual presence (SVP) through a video, which is irrespective of whether the present companion themselves can be seen through their video. The SVP contribution as an MPE-m is discussed in more detail in **3.1.3. Self-Visual Presence (SVP)** section below. The second factor of video co-presence is companion-visual presence (CVP). The CVP impact is discussed in more detail in **3.1.2. Companion Visual Presence (CVP)** section below. The third contribution to co-presence is explored at an interaction level. We test whether video co-presence is an additive factor or being video self-present (SVP) and having visually co-present companion (CVP), rather than individual factors. The experimental design and analysis discussed below in **3.1.5. Experimental Design and Hypotheses.**

As augmented social communication transcends beyond mere entertainment, into fields with more sensitive population, such education and wellbeing (O'Connor, 2019), it is crucial we understand more about virtual impact on social and cognitive brains.

The results of experiment one (**Chapter 2**) demonstrated that the online co-presence with any video-present companion improved participants' cognitive performance outcomes, in contrast to performing alone, demonstrating the Mere Presence Effect (MPE). The MPE was driven by the embodied co-presence with a visibly active companion, irrespective of companion's monitoring behaviour or agency, such as whether the companion is another person (implying second-person mentalising) or an AI-driven (non-mentalising) embodied agent. The results for AE however showed that although attentive monitoring indeed affected the participants performance only when in presence of human-minded companion (as predicted), the avatar affected participants performance differently from the realistic video present real-human. Deriving from experiment one, the video compresence (MPE) facilitated performance on difficult task. The AE significantly sped up performance for the avatar companion on the easy task, whilst marginally decreasing easy task accuracy. For real-human companion the AE marginally improved difficult task performance. Therefore, the results of experiment one show that mere co-presence elicits social impact, and that AE could be dependent both on the mind of companion and potentially their visual property, considering the different impact trends in human-minded companion groups.

The focus of experiment one was to establish whether SFE can be elicited through its mechanisms, the MPE-m and AE-m, in the videoconference-based setting. The experiment one did not explore the underlying factors of the AE-m and MPE-m which might elicit this effect. For example, the factors in experiment one did not explore which properties of the virtual co-presence mechanisms drove the effect in MPE. Testing which aspects of videoconference-based co-presence are important for MPE, self or companion presence or both, and how they interact, could reveal more about this videoconference-based impact. Experiment one also has not tested whether the visual representation of a human-minded companion matters for the AE, considering the experiment did not systematically separate companions' visual presence from its mind property. Testing whether companions' visual properties matter when monitoring, could elucidate the trends found in AE results, in which visual attributes of human-minded companions affected performance differently. The main purpose of experiment one was to establish the MPE and AE related impact in its most holistic form, arriving at maximal impact that could be elicited with the current cognitive task. Now that the baseline impact is established, the current experiment will utilise the advantages of the videoconference-based messenger to parse the social context mediated performance impact further (see **Chapter 1: Parsing Virtual Mind and Body Presence**).

Building upon findings in experiment one, the second experiment focused on systematically breaking down the predicted SFE effects, the MPE and AE, based on their mechanisms even further, to find the minimum viable underlying social contexts which might elicit these effects. To do so, the AE was broken down to its core feature of participants' performance being monitored by a companion via screen sharing, versus when participants' task performance is not visible. This approach differs from experiment one, during which the task monitoring occurred always alongside the visual co-presence of the participant and their companion. Similarly, as the AE, the MPE was also broken down into smaller components, namely, the two sides of co-presence: the mere video presence of the companion (the avatar) and the mere video presence of self, i.e., the participant's video self-presence in the video feed when in presence of companion. This approach differs from the experiment one in which the companion and participant were always visually video co-present, therefore it was not possible to parse the contribution of each level of presence.

Considering that the first experimental paradigm was designed to generate and measure the overall impact of co-presence, the dynamics of co-present impact remained untested, therefore need to be explored in the current experiment. This experiment is utilising the same videoconference software (Zoom messenger) as the first experiment; however, the participants are now given more control over the levels of virtual self-presence. This video interaction platform permits selective sharing of both the online video and performance screen sharing on-demand, creating a sufficient interactive context for the systematic investigations of our variables of interest. This software permits separation and combination of perceived social interaction levels in a way that is convenient and intuitive to the participants, as many participants have been using the messenger throughout the years of the COVID-19 pandemic. Additionally, due to digitally altered video communication becoming more mainstream over the last few years, (i.e., augmented reality video filters and avatars), there is an opportunity to test interaction with the avatar companion without creating an unrealistic communication context. Importantly, applying these methods to the current research enables the opportunity to disentangle social effects of interest in ways the real-world face-to-face communication would struggle, while maintaining reasonably sufficient ecological validity of remote communication, testing participants online from their own homes.

The following sections focused on how these levels manipulated in the current study are expected to impact participants performance. Within the following paragraphs I discuss why the avatar companion presence could be different than presence of another person or no visual presence at all. Then I will discuss how the levels of companion visual presence, self-visual presence (such as video presence of the participant) and performance screen-sharing (performance visibility) could contribute to the MPE and AE related impact, independently and additively. The reviewed discussion will end with mapping the factors of companion visual presence (CVP), self-visual presence (CVP) and performance screen-sharing (PSS) onto the MPE and AE related impact, followed by the experiment and results.

3.2.1 Avatar Virtual Companion

As discussed in the first chapter, the avatar is an interesting virtual companion, as it is a hybrid of a human mind, and a virtual body. In many ways, the interaction resembles an interaction with real humans, especially when it comes metalizing related tasks, such as in trust games between avatars (Riedl et al., 2014). However, the occlusion of the virtual body seems to activate participants brain regions differently than when interacting with a real person (Riedl et al., 2014) and the anonymity of the avatar when participant is self-exposed can lead to less trust (Joinson, 2001). This different level of observed behaviour towards avatar, at least in the current technological climate, could be explained by avatars not being able to realistically transfer the emotions and actions of their user (the person behind an avatar). This uncertainty over the avatar companion's real user states, could be heightened when participants themselves are realistically exposed to the occluded companion through self-video presence. However, considering that the AE can be elicited through the mere belief of performance being monitored by another person, even if the observer is not visually seen (Dumontheil et al., 2016), it is unclear why the interactive presence of an avatar, occluding the realistic observer, affects AE differently from the monitoring by a real human video companion. As seen in the experiment one. Therefore, one of the questions positioned in this experiment is whether the visual presence of an avatar impacts participants performance differently than when this virtual avatar companion cannot be seen at all.

It is likely that an avatar, in contrast to a real-person video or an AI-driven agent, is potentially a more complex social stimulus, especially when it attends to the participants' performance. This is due to avatar having a human mind and virtual body occluding the companions real emotional states. As per the threshold model of social influence (Blascovich, 2002), the avatar's overall social influence is potentially enhanced over its visually identical AI-agent, due to the avatar's main characteristic of being a virtual visual proxy for another mentalising person. Indeed, research shows that when playing interactive games, the participants feel upset by the social exclusion of avatars but not AI-agents (Kothgassner et al., 2017). Since the avatar is perceived as a mentalising companion, their social presence could be especially arousing to the participants, when the performance changes are expected to be dependent on another person's mentalising abilities, such as in the AE. Therefore, the AE-based performance facilitation by an avatar should employ similar mentalising qualities as for the real person companion. But, as mentioned in the previous paragraphs this is not entirely the case.

The avatar's unique feature of bridging the human mind and a virtual body could have a potential downside when it comes to social facilitation without distraction. Research demonstrates that both socially meaningful (faces: Lavie et al., 2003) and unusual stimuli (even if subtle: Jeck et al., 2019), attract more visual attention over their non-social or habitual equivalents. Indeed, results from the study, contrasting video and virtual avatar communication, confirm that participants report the communication with avatars as more distracting than the live video meetings (Junuzovic et al., 2012). Consequently, the process of coupling avatars' qualities of acting as a reflection of another person's attentive mind (during monitoring) with the avatars' unusual interactive presence, can lead to potentially additional social distractor properties contrasting to the real human video presence, or no visual presence at all. Therefore, in experiment one, the avatar which monitors participant's performance (AE) could have in principle facilitated the difficult task performance similarly to the real-human condition, however, the larger distraction impact potentially modulated the facilitation effect, leaving a residual performance change only in the easy conditions that were not originally facilitated through the SFE. This emergent facilitation-distraction effect would be in accordance with the distractor/conflict social facilitation model proposed by (Sanders, 1981), which suggests that during SFE, the levels of social distraction during focused task interact with the difficulty of the performed task.

To confirm whether the attentive avatars facilitate and distract performance as assumed in the SFE, further investigation into the cognitive impacts of avatar companion requires a direct contrast between the avatars monitoring presence (attentively monitoring, but not visually present) and its visually present monitoring (the avatar being video present during its monitoring of participants). The experimental manipulation in experiment one did not permit a systematic separation of avatars' attentive visual presence levels. Therefore, the first objective of the current experiment is to systematically vary avatars' attentive presence, by having the avatar switch their video presence either on or off, as the participants perform cognitive tasks at different levels of virtual self-display. The avatars visual video presence is measured as companion visual presence (CVP).

3.2.2 Companion Visual Presence (CVP)

The classic MPE suggest that the mere co-presence with others impacts participants' performance, possibly due to motivational properties of vigilance and uncertainty towards other people’s actions in the shared physical environment (Guerin, 1986) and increased arousal required to maintain attention between the social stimuli and task at hand (Sanders, 1981; Sanders et al., 1978). Experiment one demonstrated that the MPE is also generalisable to the remote online video conference-based social interactions, by facilitating participants' cognitive performance. Considering, that even a non-interactive humanlike body motion through a video seems to elicit social arousal (Williams et al., 2019), it seems, that the same mechanisms which are impactful in the real world MPE, might also be the driving forces behind the video-interaction MPE. The facilitation, of course, would only occur if the social interactive situation is perceived as overall motivating, i.e., participants performance is not directly judged and the monitored task seems manageable, in contrast to threatful, i.e., when the task performance is explicitly judged, whilst being uncomfortably difficult or overbearing (Blascovich et al., 1999; Grant & Dajee, 2003; Sanders, 1981).

In addition to the motivating arousal responses reported in the literature, it has been demonstrated that being co-present in the interactive environment with a companion can lead to more conforming behaviours, even if the companion does not possess a mentalising property (Hertz & Wiese, 2016; Kyrlitsias et al., 2020). Therefore, it is possible that an interactive presence of avatar could act as a visual reminder to the participant of someone else being active within their interactive space, boosting vigilance and pro-social behaviour of completing the task, as expected of them by the experimenter.

As mentioned in the introductory paragraphs above, in addition to the facilitative properties, the presence of the avatar can also potentially function as a social distraction. Therefore, the impact of visual presence of an avatar needs to be investigated further. The current study will test the effects of CVP in isolation and as a function of a classic co-presence related social impact, alongside participants self-video presence, as found in experiment one. Additionally, the study will explore whether avatars' visual presence impact is dependent on whether the avatar companion attentively monitors participants performing during the study. To do so, the attentive monitoring of participants performance will be contrasted under conditions when avatar companion is visually present versus not present.

Arguably, when testing the AE and MPE related to co-presence, both of the effects might be highly depended on participant themselves being is visually present. The paragraphs below discuss the implications of these self-exposing factors for MPE and AE.

3.2.3 Self-Visual Presence (SVP)

The MPE is often viewed as a response to the external stimulus of others in the environment, the MPE-m being the co-presence of others. However, it can be argued that without the participant attributing themselves as being part of the social interaction, their perception of the social situation’s chances. The change occurs on the fundamental level, such as by no longer perceiving self as present co-actor in the environment with others. By not being a co-actor in the social context, the social processing experienced towards the virtual companion is arguably no longer of second-person cognition. By seeing the companion, but not exposing self, the participant is just observing the social presence of companion from the first-person perspective. The cognitive mechanisms involved in just observing the social situation and being part of the social context differing on the fundamental level (Redcay & Schillbach, 2013). Therefore, the question is, whether the SFE can even arise without the self-awareness and involvement which second person cognition brings through the self-presence in the social environment. As discussed in chapter one and two, the AI-agents potentially elicit MPE due to their humanoid appearance and the social heuristics generalised towards human-like social companions (Nass & Moon, 2000). However, the question is, would virtually companion presence be socially engaging, as per SFE, if it was merely present in the messenger window without the participant themselves being video present along-side them. In other words, is the MPE based co-presence possible without self-presence. And how much does the self-presence in virtual interaction contribute to the SFE phenomenon.

The contribution of SVP in the context of AE is more intuitive, when performance is monitored and participants are judged on their performance, being also visually seen can add to the effect. The contribution of SVP to performance monitoring will be tested in the current study as part of AE, for more see **3.1.5. Experimental Design and Hypotheses**. However, the role of SVP as just a social exposure, without explicit monitoring or performance judgement, such as in MPE, is not clear. In recent years, a growing number of research suggests that an increase in self-presence through a video of self (not task performance) is an arousing driver for a socially motivated change, both on behavioural (van Rompay et al., 2008; Yu et al., 2015) and neurofunctional levels (Platek et al., 2005; Somerville et al., 2013). These changes occur during the participants' belief of being potentially visible through a camera, without explicit confirmation of whether they or their actions are being monitored, such as in the case of present security cameras (van Rompay et al., 2008). The cognitive impacts of self-presence are demonstrated in a report showing that just being video present broadcaster remotely through camera, alongside video visible classmates in videoconference, boosts memory retention of the learned material. This effect emerges in contrast to when learning alone, or when just seeing video present classmates during an online class but not being visually seen by the classmates through video (Austin et al., 2021). These findings could suggest that just the sense of being visually present (exposed to others), without being necessarily attentively monitored, such as is the case in the MPE, could lead to significant change in cognition and behaviours.

At first, it might seem that Self Visual Presence (SVP) as seen through a video could be driven by processes similar to reputation management, as in AE. However, instead of evoking the performative reputation management gestures such as in AE (Cañigueral & Hamilton, 2019; Gallup et al., 2016; van Rompay et al., 2008), being visible through video seems target other self-awareness related processes, for example checking own image or posture (Miller et al., 2017). Arguably, without a clear indication of being evaluated and why, these processes reflect self-referential cognition related to vigilance and social preparedness rather than reputation management *per se*. Additionally, in contrast to the AE related processes, when participants have clear understanding of confederates' interest in monitoring, the video self-presence-based cognition is possibly driven by the social uncertainty. Without a clear monitoring initiative related to AE, during just self-visual presence, similarly to MPE, there is no explicit indication of when, why, or whether, the companion is paying attention to the video of the individual. This state of uncertainly over being potentially seen, without clear indication of the motive or timing of the attention from the video companion, induces vigilance and state of preparedness. The state of vigilance could be similar to the MPE-m discussed in the real-world MPE by Guerin (1986). The real-world MPE responses also seem to demonstrate a similar pattern of self-reflective implicit cognition, as participants non-verbal demeanour shifts to more constrained, including posture changes, irrespective of whether the co-present companion is watching (Guerin, 1983). During videoconference-based interaction, the importance of maintaining a sufficient self-visual (but not competence or performance) representation during video-based communication can be observed through a drive to self-monitor own videos during video conference-based interactions (George et al., 2022). The people who are inclined to higher levels of self-image, experiencing more zoom fatigue when their self-camera (participants own camera) is on (Shockley et al., 2021). Therefore, as with seeing the presence of another person in the same room, humans are not indifferent to the mere potential exposure of self to others. In the real-world communication scenarios, the isolated level of self-presence is not a regular issue, as people interact mostly on equal exposure basis. However, in virtual communication, the self-presence through video exposure can occur without a seeing the social companion visually, for example when their cameras are switched off. Exploring whether the level of self-exposure irrespective of whether the companion can or cannot be seen is an important factor influencing the performance change as per SFE.

Considering the self-visual presence to companion induces self-awareness and is an important factor within a video interaction context, with both facilitating and fatiguing qualities, it is substantial to explore these effects of self-presence on cognitive performance. In the current experiment the participants will perform the cognitive task (RRP) whilst having their video feed to companion turned either on or off. The effect of self-visual presence (SVP) is tested as part of MPE, both in isolation as mechanisms of social arousal through self-reflection, as well as within a larger interactive social context, such as co-presence (interacting self-reflection with companions' responsive presence). In this experiment, the SVP is classified as MPE-m when it is irrespective of whether participants performance is monitored. This decision was made with appreciation for the cognitive processes which contribute to MPE, such the state of vigilance, uncertainty and preparedness when exposed to the conspecific and awaiting action. Without clear instruction of performance monitoring, the participants are just visually present without a clear goal of performance-based reputation management. For example, being just video present, without clear instruction of monitoring, shows no significant activation in reputation management networks, including mPFC (Izuma et al., 2010). However, since the self-reflective cognition, could potentially also interact with competence-based reputation management under metalizing companions gaze, the SVP will also be tested alongside and performance screen-sharing as part of AE. The performance screen-sharing is investigated as catalyst of the AE in virtual interaction, both in isolation and additively with SVP.

During condition when participants camera is on, in the current experiment, both the participant and the virtual companion will be able to see the participants. Participants will be able to see themselves through a self-view video. This SVP view from participant perspective differs from experiment one, in which participants could not see their video in self-view window during attentive and non-attentive presence. As experiment one did not separate SVP from PSS or CVP, we wanted to assure that there is no self-view distraction effect we cannot account for when measuring virtual MPE and AE. The current experiment test SVP directly, including the potential distracting or facilitating nature of self-view when sharing own video.

3.2.4 Performance Screen-Sharing (PSS)

Experiment one revealed a marginal AE during task monitoring by the mentalising companions, the real-human and the avatar, but not non-mentalising AI-companion. However, unlike the significant MPE, believed to be driven by the social uncertainty and vigilance in a mutual environment, the attentive presence has not reached a significant meaningful facilitation effect for avatar companion in experiment one. As discussed, prior, one of the potential contributing factors to poorer task facilitation during the AE, could be the facilitation-distraction effect of avatar, where participants are both facilitated due to being monitored by the mentalising other, yet significantly distracted by their unusual monitoring presence. Therefore, this experiment will test the AE as task monitoring, irrespective of companion presence first, and then by testing performance differences of monitoring performance under present and absent avatar companion. Firstly, however the current study will investigate the performance-based AE in its minimal viable form – as participants believe that their task performance is being watched live through screen-sharing.

The performance facilitation on AE is shown to be affected by the subjective disposition over personal competence on the task, or the task novelty, and whether the task is objectively assumed to be more difficult or not (Blascovich et al., 1999; Grant & Dajee, 2003). Most of the AE research associates the effect with participants competence on the task and the anxieties related to the task outcomes when monitored. Task monitoring by another person has shown to be impactful on the performance outcome, irrespective of visual presence of the performer or the monitoring companion. For example, the research into occupational task performance monitoring software demonstrates that even electronic task monitoring, can elicit AE. When monitored, the participants who perceived themselves as more competent performed better, and the less competent performed worse with electronic task monitoring versus without (Aiello & Kolb, 1995). The worsening of performance through task monitoring was higher when the stakes of tasks performance outcomes were raised, such as when employees were electronically monitored at their workplaces (Aiello & Svec, 1993), or when employees could not control when the performance monitoring occurred (Stanton & Barnes-Farrell, 1996). The lack on need for companion presence has also been demonstrated in the laboratory setting, where AE was elicited without the visually present task observer, by just implying observation (Dumontheil et al., 2016; Wolf et al., 2015). Therefore, as long as the participant is aware that their task performance is monitored by someone, and they have some accountability for their task outcomes, the process of task monitoring should elicit AE based SFE, irrespective of whether they are seen or can see the companion, or potentially be visually seen themselves. The current research will test whether this indeed the case. The current experiment investigates whether performance screen-sharing (PSS), through the video chat screen-share feature, is sufficient to elicit AE irrespective of other factors, such as participants self-video presence (SVP) or companion visual presence (CVP). If the effect is not significant, it is possible that the AE may be an additive effect of both the participants sense of being monitored as a performer (SVP, see above) and the performance screen-sharing outcomes (PSS).

The following sections describe how the factors such as PSS, SVP and CVP interact within the experimental analysis, and map onto the hypothesised MPE and AE mechanisms.

3.2.5 Experimental Design and Hypotheses

In experiment one, we found that the mere online video co-presence facilitates participants' performance and that there is a marginal, yet interesting, effect of monitoring (AE), especially in the avatar group. Although the first experiment showed that MPE is effective in eliciting performance change, it is not clear, whether it is the MPE of companion visual presence, the MPE of just being self-video present, or a combination of both of these social contexts that really drives the effect of MPE. It was also not clear whether the unique avatar companion presence might be both a facilitating and a distracting stimulus, especially during the AE. Considering the avatar AE impact trend in study one, this could be the case.

To explore the effects further, the current experimental design systematically manipulated three social interaction factors: video self-exposure, in the form of self-video presence (SVP: both participant and companion can see the participants video feed), the participant screen sharing their performance for monitoring by companion, in the form of performance screen sharing (PSS), and the Companions Visual Presence (CVP), in the form of either visual or not visual avatar companion. See **Figure 3.1** below for diagram illustrating the summary of factors and their corresponding levels in the current experimental design.

Figure 3.1

The Schematic of Independent Variables and Corresponding Levels in Experiment Two.

Experiment Two: Design Summary

IV 1: Within-Subjects	**IV 2:** Within-Subjects	**IV 2:** Within-Subjects	**IV 3:** Within-Subjects
SVP: **Self Visual Presence**	**CVP:** **Companion Visual Presence**	**PSS:** **Performance Screen Sharing**	**Difficulty**
Off On	Off On	Off On	Easy Difficult

Experiment One Companion
Companion Type * One Companion Type
Avatar

* Only one level of Companion Type was used in this study. The avatar companion was either visually present through the video to the participant or visually absent, IV factor Companion Visual Presence (CVP).

DV 1: Accuracy (%), **DV 2:** Reaction Times (ms) per accurate responses only
SFE: Better performance on easy and worse on difficult tasks, when in social context versus when not.

These factors will be turned either on or off based on the study command, as the participants performs the cognitive task. Each of the factors is assigned an independent SFE driven impact potential, at two difficulty levels (easy, difficult). As per the SFE, the performance of easy task should get better, and the performance of difficult task should get worse, in social context versus when it is tuned off in the videoconference software. The study will analyse whether these three factors impact participants' cognitive performance either in isolation or as an additive trend of increased virtual co-presence. Considering, experiment one has not found the canonical SFE effect, it is possible that the effect will not fall into the classic SFE interaction. However, the separating the social influence levels might lead to a clearer SFE effect, otherwise explain the pattern of results in experiment one in more detail.

Based on the randomised commands in our current experiment, the social interaction factors can occur in isolation or with other factors turned on. The participants are told when each condition will occur. For example, when the performance screen-sharing condition comes up, the participants are shown a mark that their performance is now attentively monitored (they have to turn on their screen-share), otherwise they just perform with their camera or companion cameras off or on, without the performance being shared. The participants are told that they are testing an online marking software, making sure, that they do not overthink the manipulation of the social context. This study aims to untangle how different levels of videoconference interaction impact the cognitive functioning of neurotypical participants. The findings will contribute to further development of in-depth understanding of the relationships between the innerworkings of the social brain and its interaction with executive cognitive processes, and hopefully alongside paving a way towards the development of more mindful social interactive technologies and wellbeing focused coping strategies in an increasingly more virtual social world.

All the effects discussed above are tested at each difficulty level, investigating a difficulty × social context interaction, with predicted SFE related impact of performance on easy task becoming better and performance on difficult task worse, when in social condition is virtually turned on versus off. I set out the following main hypothesis relating to MPE and AE.

Hypothesis One (H1): Mere Presence Effect (MPE). The MPE impact in the current study is tested at three levels. See **Figure 3.2** below for diagrams illustrating the summary of factors and their corresponding levels analysis mapping onto the MPE hypotheses. The three MPE related hypotheses are listed below.

Figure 3.2

Schematic of Independent Variable Mapping onto the MPE Analysis in Experiment Two.

Experiment Two: Design Summary

IV 1: Within-Subjects	**IV 2:** Within-Subjects	**IV 2:** Within-Subjects	**IV 3:** Within-Subjects
SVP: Self Visual Presence	**CVP: Companion Visual Presence**	**PSS: Performance Screen Sharing**	**Difficulty**
Off On	Off On	Off On	Easy Difficult

Experiment Two: Mere Presence Effect, H1.a

IV 2: Within-Subjects	**IV 3**
CVP: Companion Visual Presence	**Difficulty**
Off On	Easy Difficult

H1.a: The MPE will be elicited through seeing the companion on video (CVP: on) versus when companion cannot be seen (CVP: off), irrespective of whether performance efficiency can be monitored(PSS), or participants themselves are visible (SVP).

- Testing whether being able to see the virtual companion through the video window elicits MPE

Experiment Two: Mere Presence Effect, H1.b

IV 1: Within-Subjects	**IV 3**
SVP: Self Visual Presence	**Difficulty**
Off On	Easy Difficult

H1.b: The MPE will be elicited by being self-exposed though the video (SVP: on) versus when the participant is not seen (SVP: off), irrespective of whether performance efficiency can be monitored(PSS), or companion is visually seen on the video (CVP).

- Testing whether being merely visually present online irrespective of being monitored, elicits MPE related performance change

Experiment Two: Mere Presence Effect, H1.c

IV 1	**IV 2:** Within-Subjects	**IV 3**
SVP: Self Visual Presence	**CVP: Companion Visual Presence**	**Difficulty**
On	Off On	Easy Difficult

H1.c: MPE will be elicited as a combination of being self present on camera (SVP: On) and seeing the companion being visually present (CVP: On) versus when companion is not video visible (CVP: Off)

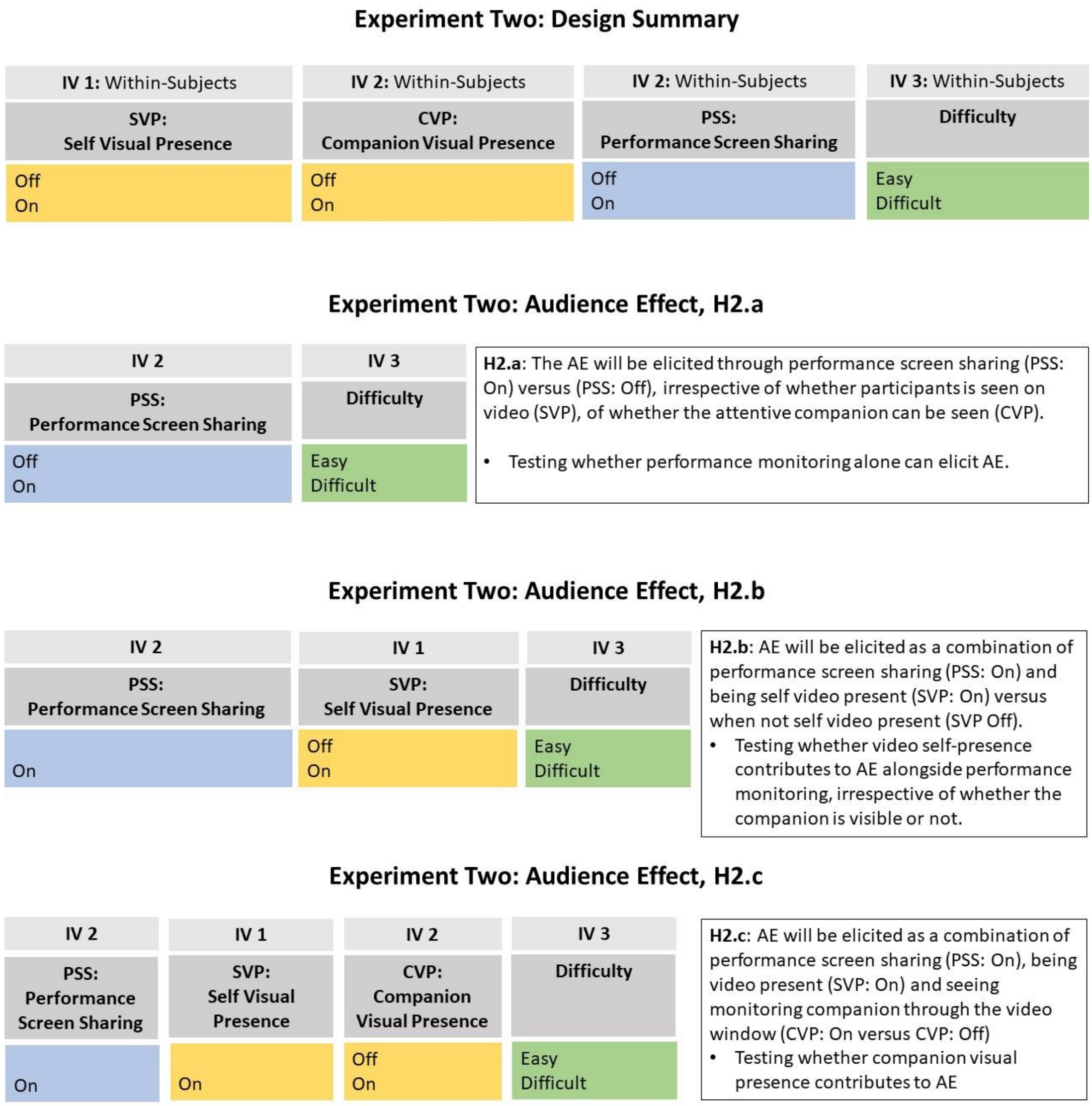
- Testing co-presence, whether companion visual presence contributes to the MPE alongside being exposed to the companion

Firstly, because the MPE hypothesises that SFE rises due to uncertainty of conspecific actions within the shared environment, irrespective of who they are or whether they are actively judging or monitoring the participant. Whether the avatar is visually present, and the actions of the avatar, are not directly visible when participants are focused on the task. This could raise such level of uncertainly over the companion. Therefore, the hypothesis ***H1.a*** predicts that the companion visual presence (CVP: on) versus absence (CVP: off) will elicit SFE. Additionally, as argued above, without the visual presence of self in the environment, the co-presence is not achievable, as participants are just first-person observers rather participators in the shared environment. Therefore, the ***H1.b*** predicts that participants self-visual presence (SVP), irrespective of whether they are being monitored for performance or not, will elicits SFE, due to them being merely video self-exposed, by turning their video self-visual presence (SVP) from off to on. It is possible that the companion visual presence and participants self-visual presence are independent in their effects. However, in experiment one the co-presence related facilitation was significant. Therefore, it is possible that the MPE are an additive social co-presence related phenomenon, meaning that both the companion and participant are required to be co-present for MPE to occur. If this is the case, then additive effect of adding companion visual presence (CVP: off to CVP: on), when participants is visually self-present (SVP: on) is where the MPE should emerge. The hypothesis ***H1.c*** predicts that if the MPE in videoconference-based setting is additive, based on co-presence of both parties, then there should be SVP x CVP interaction at each difficulty level. The analysis of ***H1.c*** will replicate the experiment one co-presence based MPE. The hypothesis driven analyses are conducted irrespective of performance screen-sharing, as with experiment one. The exploratory analyses will also test whether the MPE occurs under more controlled condition, when the performance screen-sharing is turned off by the participant, controlling for any carry over effects of performance monitoring.

Hypothesis Two (H2): The Audience Effect (AE). There are three AE related hypotheses postulated in this study. See **Figure 3.3** below for diagrams illustrating the summary of factors and their corresponding levels analysis mapping onto the MPE hypotheses. The three AE related hypotheses are listed below.

Figure 3.3

The Schematic of Indpendent Variable Mapping Onto the AE Analysis



The AE assumes that SFE arises due to mentalizing processes relating to others' judgment of one's performance. The AE can arise without being able to see the monitoring person, as long as the participants believe they are monitored by a mentalising other. Therefore, if the performance monitoring, without being visually seen though video is sufficient for AE, the ***H2.a*** predicts that SFE should be elicited through turning performance screen-sharing (PSS) from off to on, irrespective is visual self (SVP) or companion (CVP) presence. However, if the AE is reliant on being also self-exposed during the performance sharing, then ***H2.b*** states that there should be an additive effect of turning self-visual presence on (SVP: off to SVP: on), when performance screensharing is on (PSS: on). Additionally, if avatars virtual presence contributes to the AE, turning the companion visual presence on (CVP: off to CVP: on) when performance screen-sharing (PSS: on) should lead to better easy and worse task performance, as per SFE. Unless CVP is distracting, as mentioned in the *Avatar Companion* subsection, then the performance should decline. Therefore, ***H2.c*** predicts that if companion visual presence is socially arousing, as per SFE, then the performance should change according to SFE when in presence of CVP: on versus CVP: off. Otherwise, the significant drop in performance will suggest social distraction by companion.

3.3 Methods

3.3.1 Participants

Out of thirty participants recruited, 27 participants (20 female, 7 male), age range 19-45 (*M* = 27.2, *SD* = 7.7), working or studying in London, United Kingdom, were entered into the final within-subjects analysis. Our participants were recruited within a neurotypical population from various ethnic backgrounds, self-reported as not having a clinical diagnosis of autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), or anxiety disorders.

The target analysis sample size, *N* = 24, was estimated using G*Power, at $1-\beta = .8$, $\alpha = .05$, Cohen $f = .44$, with additional six participants (25 per cent of sample estimation) to account for any potential drop-offs due to the unexpected technical issues or not believing the study script (see *Participant Exclusion* below). The sample estimation was motivated by a significant 2 (Audience) x 2 (Task) within-subject AE-based interaction using the same cognitive task (Dumontheil et al., 2016b), performed in our study. The drop off percentage was estimated based on the drop-off rate in our earlier similar video-based paradigm (Sutskova, Senju, & Smith, 2021).

The participants were enlisted through an online participant recruiting system (SONA), advertised by targeting individuals with an interest in technology. All participants were required to have access to a personal computer with a working keyboard, a video conference ready camera and audio setup, and a stable internet connection. The study was approved by Birkbeck, University of London, Psychology Department Ethics committee, approval number: 192084.

Participant Exclusion

At the end of the study, all participants were asked whether they believed that the avatar used in the study was indeed tracking researchers' body motion and gaze behaviour, during researcher video present conditions (CVP: On). The analysis was conducted only on the participants who explicitly confirmed their belief in avatars representing the researcher. Three out of thirty participants reported that they did not believe in Avatar representation. There were no explicit technical issues (internet connection, hardware, or software) reported for the remaining twenty-seven participants that were entered into the final data analysis phase.

3.3.2 Design

As per our pre-registered experimental design (OSF: https://osf.io/uqvyr), we have systematically manipulated four within-subjects factors, the Self-Visual Presence of the participants' video to the virtual companion (SVP: Off, On), Shared Performance Presence of participants task screen to the virtual companion (SPP: Off, On), Companions Visual Presence in the participants' companions (avatar) video window (CVP: Off, On), and the Difficulty of the cognitive task performed by the participants (Difficulty: Easy, Difficult). Similarly, to Experiment One (**Chapter 2**), we have used the Relational Reasoning Paradigm (RRP), a visual logic task, susceptible to the SFE (Dumontheil et al., 2016) and the virtual presence effects in a similar online paradigm published by us prior (Sutskova, Senju, & Smith, 2021). As in experiment one, the participants' cognitive performance on the RRP task was measured both in per cent accuracy and in reaction times (RT) per accurate responses only.

3.3.3 Software

Communication

The video conference-based interaction between the participant and the researcher was established using currently widely used online video chat software, Zoom messenger (Zoom.us). Both parties (experimenter and participant) were using the messenger features to share their video and audio, throughout the remote communication from their homes. The participants were using the Zoom messengers screen-share option, to project their task display to the researcher, when asked to do so.

Task

The cognitive task was developed within an online experimental task engine Gorilla (Gorilla.sc), enabling participants access to the experiment from their homes. On the testing day, the researcher provided the participants with an individualised anonymous ID to log in to the session. Gorilla task engine acquired both the participants' anonymous task performance information and participants' personal information, such as participation consent and participants' demographics information (gender and age), separately from the task performance outcomes.

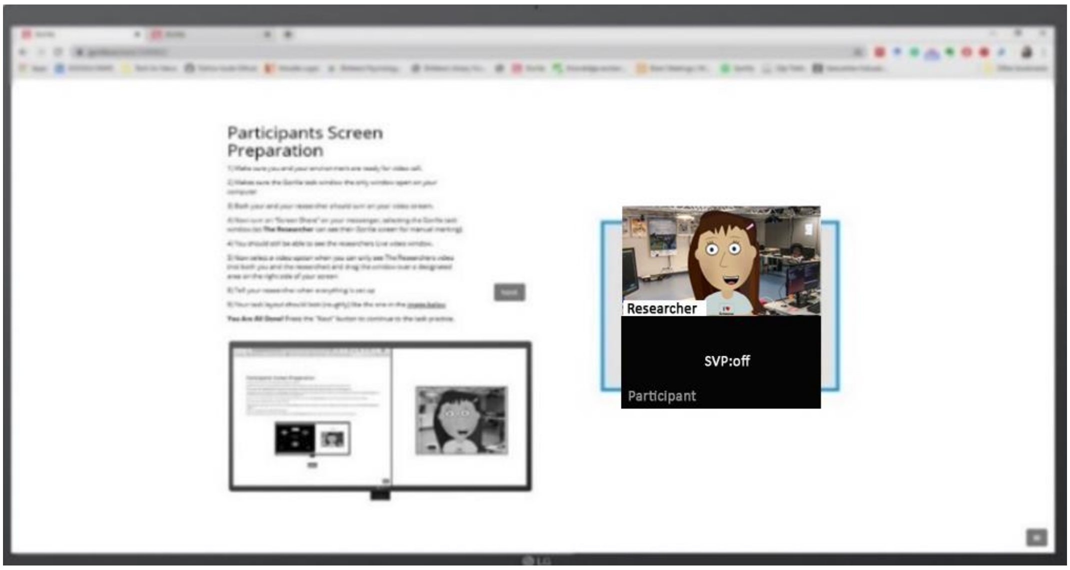
Avatar

Companions Visual Presence (CVP) in this study was represented by an interactive avatar, which was developed to track the online companions' (researchers) gaze behaviour and body motion. Similarly, to experiment one (**Chapter 2**), the avatar was identical animated female character, as in experiment one, see **Figure 3.4**, with animated dynamic gaze, mouth, and upper body and head motion. Similarly, to experiment one, the avatar character was animated via Adobe Character Animator software in real-time, by tracking researchers' body motion and gaze-shifts through their video camera, lip-synching was accomplished by mapping researchers' audio input onto the characters' mouth motion. The live avatar footage was virtually projected into the Zoom messengers’ companions' video feed window through an open access live video broadcasting software, virtual camera option. The avatar was active throughout the study session, as the researcher was attending to participants' screen-shared performance or their video of self.

Avatar Used for CVP Condition Arranged Alongside Participant Video Window (SVP)

Figure 3.4

Avatar Used for CVP Condition Arranged Alongside Participant Video Window (SVP)



Note. The Avatar (CVP) when visually present were facing the screen, talking to the participant during the introduction session. The lip-synching (and the smile) was mapped from the researcher's live web camera input, as the avatar video is streamed through the Zoom messenger hover window.

At the beginning of the introduction, both the participants' cameras and screen-share were turned off, making sure their computer and home environments are fit for visual sharing during the study. After participants confirmed the environments are appropriate, they were asked to turn on their media.

3.3.4 Cover Story & Conditions

Both the levels of social contexts and task difficulty levels on the RRP task were utilised as stimuli to elicit changes in participants' cognitive performance output.

Difficulty RRP

The cognitive task used was identical to the task used in the first experiment, which is a modified version of the visual logic task, Relational Reasoning Paradigm (RRP) that prior to demonstrating susceptibility to the SFE (Dumontheil et al., 2016). The task consisted of two difficulty levels of timed visual pattern and shape matching tasks. The easy task level consisted of three images, two at the top and one at the bottom. The participants were asked to either match shape or texture (never both) of the top row images to the image on the bottom row. If the top and bottom row matched (in shape or pattern), the participants clicked the right arrow for “yes”, if not, a left arrow for “no”, For the difficult level, participants had to focus on the dimensions of changes occurring at the top and bottom rows of the task and decide whether the top and bottom row images change in the same way. Each difficulty condition, either easy or difficult, was performed in blocks of five trials. Each social context condition consisted of four easy and four difficult blocks presented in randomised order. As with experiment one, the task window was always presented on the left side of the participants' screen, whilst the video windows were always hovered in the white box on the right side of the screen.

Cover Story

To avoid the confound of participants guessing the social nature of our study manipulation, we implemented a minor social deception (ethics approval granted). This step assured the participants focus on the cognitive task, without overanalysing the social interaction changes they actively partook in. All participants were told a cover story that we are testing a new online-testing-software similarly experiment one (**Chapter 2**), which gathers users' self-video or screen-share task data to predict their performance in real-time. The researcher (in Avatar form) was believed to be accompanying the participants to manually note down their performance, as seen through participants' screen share. It was suggested that the researcher will later compare their notes against the predictive program.

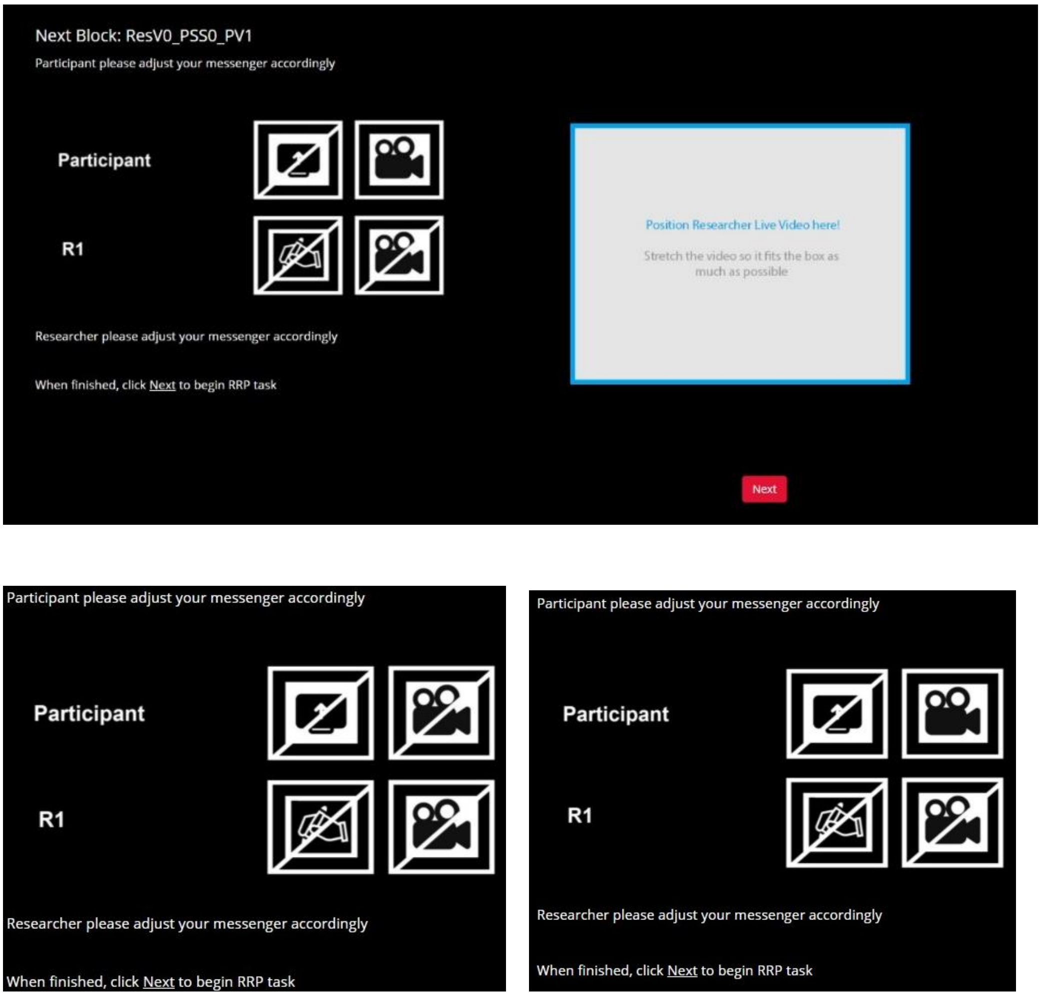
Media Switching

The participants believed that due to our online-testing-software being a pilot, we wanted to make sure that it works well under different media processing loads. The participants were reassured that the researchers' avatar was supposed to induce a higher processing load for the program, than the video of the researcher, therefore the avatar needed to be used throughout. To control for other media loads, both the participant (SVP) and the researcher (CVP) were required to turn their video shares on or off, as directed by the on-screen software instructions. Additionally, the participants had to make sure that their screen-sharing (SPP) is also either visible or not visible, as dictated by the software. The instructions of media switching were presented as onscreen notification icons, stating which media should be switched on or off for the next trial block, both for participants and the researcher, **Figure 3.5**.

Task View Instructions for The Participant and The Researcher

Figure 3.5

Task View Instructions for The Participant and The Researcher.



Note. The top figure demonstrates the media setup instructions, as seen from the participants' perspective. The instructions were always presented on the left side of the screen, whilst the video windows (with SVP, CVP) were always hovering in the white box on the right. The red “Next” button on the right was clicked when participants finished their media set up and were ready for the new task block.

The bottom two figures are close-ups of the instruction's windows. The arrow icon (as per Zoom messenger) represented the SPP condition (screen share), whilst the camera icon (as per Zoom messenger) represented camera switching both for the participant (SVP) and the researcher (CVP). The cross over icon meant that the media was supposed to be turned off. Since the researcher was believed to be part of the online-testing-software piloting, R1 in the instructions represents a row for researcher media switching, with the writing hand icon suggesting whether participants' performance will be noted down (writing hand icon), or not (crossed over hand icon). Reminding participants that when their screen share (SPP) was off, their performance could not have been marked by the researcher.

The bottom left figure prepares the participant for a social context block, where both the participants' media (screen-share: SPP and video: SVP), and researcher's (CVP) video media, are turned off. The bottom right figure indicates a beginning of a social context block where the participants' camera had to be turned on (SVP: On), whilst the rest of the media for the researcher and the participant is off.

Performance Screen Sharing (PSS)

For the PSS conditions, the participants were required to turn their task screen share, either on or off, based on the onscreen instructions. Switching the SPP on, displayed participants' performance to the researcher. Screenshare switching occurred alongside switching of other conditions (see *Figure 3: Participant*), during which the participants could have had an option to share their screen, whilst either being video present (SVP: On) or not (SVP: Off), and either seeing the researchers interactive Avatar (CVP: On), or not (CVP off) respectively.

Self-Visual Presence (SVP)

The SVP conditions required the participants to switch their self-camera either on or off, enabling the researcher to see participants' videos as they partake in the experiment. Similarly, to SPP, switching of SVP occurred alongside switching of other conditions. During SVP: on condition, in the current experiment, both the participant and the virtual companion could see the participant's self-view video. This was to test whether seeing self on camera might have been visually distracting to the performance. This SVP view from participant perspective differs from experiment one. In experiment one the participants could not see their video in self-view window during attentive and non-attentive presence.

Companions Visual Presence (CVP)

Similarly, to SVP, the CVP conditions involved switching of the camera, however, for CVP conditions the instructions were directed at the researcher (**Figure 2.2**, R1 row) rather than the participant. As the researcher turned the camera on (CVP: On), the participants could see the researcher's interactive avatar in their companion's video window. The CVP: off condition restricted participants from seeing researchers' video footage.

3.3.5 Procedure

Prior to participation, the participants were sent a password protected Zoom messenger link, logging into the videoconference software, being greeted by the researcher in the avatar form. The participants were told to only share their video and screen share after they are confident their computer and home environment is appropriate for the study. Participants then continued with the information sheet, consented to the study and read the cover story about the direction of the experiment. They were then directed to the software setup instructions, during which the video windows were arranged to the right side of the screen, where they remained throughout the study, with instruction and task screen remaining always on the left side of the screen (see **Figure 3.4** and **Figure 3.5**). The participants were then directed to the practice session, where they practised the RRP tasks and media switching based on the icons presented on the screen (see media switching icons in **Figure 3.5**). After successful completion participants performed the RRP task at two difficulty levels, switching between the social contexts. The social context blocks were randomised and counterbalanced between the participants. After the task trials, the participants filled in several individual differences' questionnaires. Before completion of the experimental session, all participants were asked about their belief about the avatar's representation of the researcher, followed by a full debrief of the cover story and the actual purpose of the study. Participants were given an option to retract their data after debriefing.

3.4 Results

Results for an omnibus four-way ANOVA of four factors CVP x SVP x PSS x Difficulty. Due to a significant positive skew of the data, all analysis values reported are Greenhouse-Geisser corrected.

The summary of the means and standard errors (SE) by each level in each factor of the current study are presented in the summary tables below, ***Table 3.1*** for percent accuracy and ***Table 3.2*** for reactions times in milliseconds.

Table 3.1

Means (M) And Standard Errors (SE) Of Percent Accuracy (%) All the Levels by Each Factor Within the Experiment Two Design.

Companion Visual Presence	Performance Screen-Sharing	Self-Visual Presence	Difficulty	*M*	*SE*
Off	Off	Off	Easy	90.19	1.63
			Difficult	74.07	2.49
		On	Easy	94.24	1.41
			Difficult	76.85	3.22
	On	Off	Easy	92.41	1.56
			Difficult	77.70	3.56
		On	Easy	91.22	1.43
			Difficult	80.09	3.16
On	Off	Off	Easy	88.66	2.26
			Difficult	73.52	3.62
		On	Easy	92.41	1.40
			Difficult	76.11	3.16
	On	Off	Easy	92.78	1.17
			Difficult	73.89	4.36
		On	Easy	90.74	2.34
			Difficult	79.07	3.96

Table 3.2

The Means (M) And Standard Errors (SE) Of Reaction Times (RT) For All the Levels by Each Factor Within the Experiment Two Design.

Companion Visual Presence	Performance Screen-Sharing	Self-Visual Presence	Difficulty	*M*	*SE*
Off	Off	Off	Easy	1444.47	62.09
			Difficult	1991.68	83.07
		On	Easy	1396.27	56.03
			Difficult	1868.66	70.90
	On	Off	Easy	1366.60	61.21
			Difficult	1871.65	72.09
		On	Easy	1370.34	63.34
			Difficult	1930.03	83.01
On	Off	Off	Easy	1473.31	66.62
			Difficult	1937.85	82.08
		On	Easy	1347.07	58.35
			Difficult	1899.15	85.12
	On	Off	Easy	1389.46	52.59
			Difficult	1968.81	81.35
		On	Easy	1340.28	78.64
			Difficult	1915.15	82.81

3.4.1 Difficulty

Difficult tasks were performed significantly slower, F (1, 26) = 158.8, p < .001, η_p^2 = .859 (difficult M = 1922.87, SD = 333.02, easy M = 1390.97, SD = 277.41) and less accurate than easy tasks F (1, 26) = 37.11, p < .001, η_p^2 = .59 (difficult M = 76.40, SD = 14.3, easy M = 91.60, SD = 4.60).

3.4.2 H1: Mere Presence Effect (MPE)

For the MPE, the individual contribution of effects of self-visual presence (SVP), companion visual presence (CVP) and the additive combination of both. The effects were first investigated irrespective of performance screen-sharing (PSS) by participant, replicating experiment one MPE conditions. Secondly, the effects were explored under a more controlled condition of no performance screen sharing (PSS: off) to the companion.

MPE (H1.a): Companions Visual Presence (CVP)

The analysis tested contribution of companion visual presence (CVP) to the videoconference based MPE. There was no significant CVP x difficulty interaction for accuracy F (1, 26) = 0.78, p = .78 η_p^2 = .003, nor RT F (1, 26) = 0.26, p = .64, η_p^2 = .010. There was also no main effect for CVP for accuracy F (1, 26) = 0.82, p = .38, η_p^2 = .030, nor for RT F (1, 26) = 0.01, p = .92, η_p^2 < .001. There was no significant impact of CVP per easy or difficult condition separately.

Investigating CVP impact specifically when the PSS was off, also revealed no significant differences in contribution of CVP, at each difficult level. There was no support for the hypothesis ***H1.a*** that companion videoconference-based mere presence is sufficient to elicit SFE.

MPE (H2.b): Self-Visual Presence (SVP)

The analysis focused on the contribution of self-visual presence (SVP) to the videoconference based MPE. The results revealed no significant SVP x difficulty interaction for accuracy F (1, 26) = 1.63, p = .214, η_p^2 = .059, nor RT F (1, 26) = .251, p = .621, η_p^2 = .010. The analysis revealed a main effect of SVP on participants performance, significant in accuracy F (1, 26) = 4.77, p = .038, η_p^2 = .155, and marginal in RT F (1, 26) = 3.57, p = .070, η_p^2 = .121. The main effect of SVP demonstrated that, overall, when participants were visible to the companion (SVP on), irrespective of companion visual presence or screen-sharing, they performed more accurately (SVP: on *M* = 85.10, *SD* = 9.09, SVP: off *M* = 82.90, *SD* = 8.57) and faster (SVP: on *M* = 1605.88, *SD* = 307.42, SVP: off *M* = 1647.19, *SD* = 281.88).

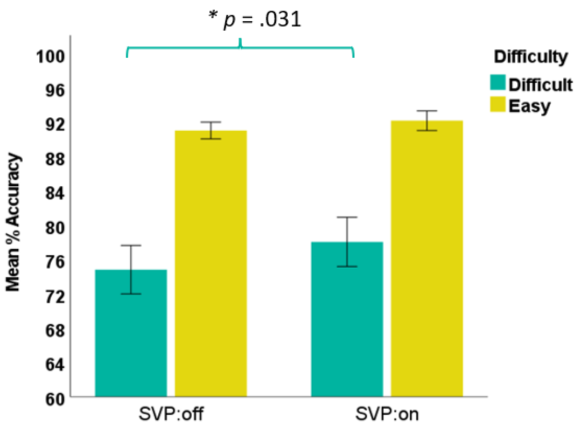
The planned follow up contrasts relating to the MPE, investigated SVP impact of each level of difficulty level separately (SVP x difficulty).

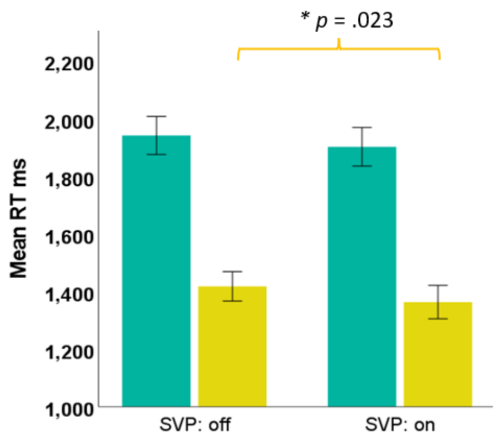
Accuracy. When breaking down SVP effect by difficulty, the results showed that turning the self-video camera on, appeared to facilitate both the easy (SVP: off *M* = 91.01, *SD* = 5.20, versus SVP: on *M* = 92.15, *S* = 5.72) and difficult (SVP: off *M* = 74.80, *SD* = 14.55, versus SVP: on *M* = 78.03, *SD* = 15.06) tasks, but only the difficult condition was facilitated significantly, difficult p = .031, η_p^2 = .168, easy p = .34, η_p^2 = .036, see **Figure 3.6.a**. This improvement on the difficult, but not easy task replicates result of the mere co-presence (MPE hypothesis) in experiment one, however there is no SFE related effect.

Reaction Times. When breaking down SVP effect by difficulty, the results showed that, although turning self-video camera on appeared to facilitate both the easy (SVP: on *M* = 1363.49, *SD* = 300.86, SVP: off *M* = 1418.46, *SD* = 265.41) and difficult (SVP: on *M* = 1903.25, *SD* = 347.99, SVP: off *M* = 1942.50, *SD* = 342.22) tasks, only the easy condition was facilitated significantly, difficult p = .27, η_p^2 = .047, easy p = .023, η_p^2 = .182, see **Figure 3.6.b**. There was no SFE related interaction, this result did not directly replicate the result of MPE in experiment one, in which difficult but not easy condition improved significantly.

Figure 3.6

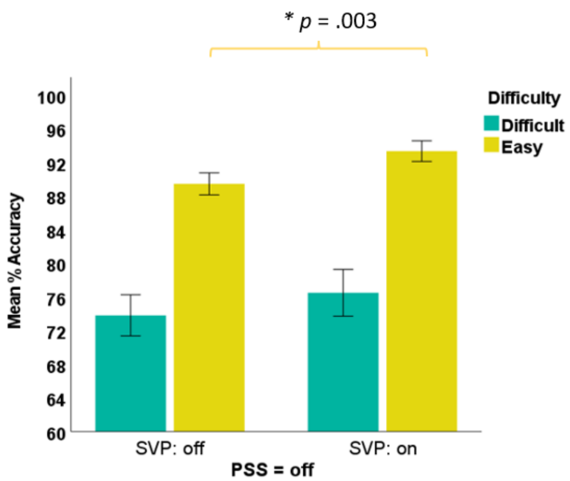
MPE Facilitation Driven by The Self-Visual Presence (SVP).

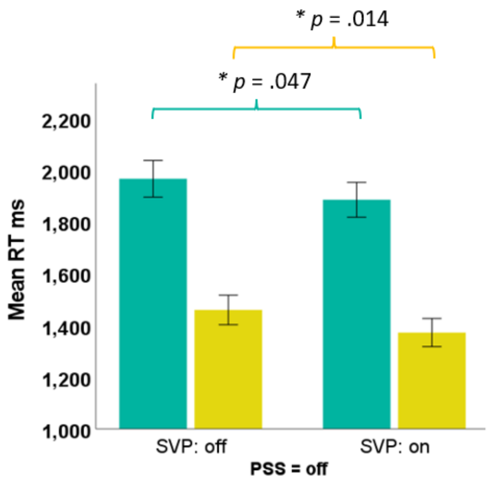




a. Accuracy: SVP irrespective of PSS

b. RT: SVP irrespective of PSS





c. Accuracy: SVP with PSS: off

***d.* RT:** SVP with PSS: off

Note. significant facilitation of difficult task in (a) accuracy, and a marginal facilitation in performance speed on easy task (b) when participants self-camera was turned on (SVP: on) versus off (SVP: off). Error bars +/-1 SE.

MPE (H1.b explorative): Self-Presence with Performance Screen Sharing Off

To control for any possible residual effects of performance monitoring, this analysis focused on the mere self-visual presence (SVP), when the performance screen-sharing (PSS) was turned off. The analysis focused on the PSS x SVP x difficulty interaction, only when the PSS level is off. This analysis could not have been performed in experiment one as the attentive monitoring and non-attentive co-presence were not experimentally parsed.

Accuracy. There was a significant PSS x SVP x difficulty interaction, F (1, 26) = 6.5, p = .017, η_p^2 = .20. The interaction was broken down by each difficulty level separately (PSS x SVP for easy and difficult condition), contrasting the SVP when performance was not seen (PSS: off). The results showed that unlike the difficult condition which improved significantly by turning the SVP: on irrespective of PSS, the easy condition was PSS sensitive (**Figure 3.6.c**). The analysis within the easy condition only, indicated a significant PSS x SVP interaction, F (1, 26) = 6.37, p = .018, η_p^2 = .197. The exploratory analyses demonstrated that when PSS was off, the easy task accuracy improved significantly, p = .003, η_p^2 = .29, by turning SVP on (M = 93.32, SD = 6.24) in contrast to when the SVP was off (M = 89.42, SD = 6.75). There was no SFE related impact (**Figure 3.6.c.)**.

Reaction Times. There was a marginal PSS x SVP interaction, F (1, 26) = 3.05, p = .092, η_p^2 = .105, and no significant PSS x SVP x difficulty interaction, F (1, 26) = .336, p = .57, η_p^2 =.013. As per planned analysis the PSS x SVP interaction was still broken down within each difficulty level (easy, difficult) separately to investigate effects as per SFE. The analyses revealed that when performance was not monitored by companion (PSS: off), having self-video presence on (SVP: on) significantly improved the speed of accurate responses (**Figure 3.6.d.)**, both for easy (SVP: off, M = 1458.89 , SD = 296.49, SVP: on, M = 1371.67, SD = 282.77), and difficult (SVP: off, M = 1964.77, SD = 367.00, SVP: on, M = 1883.91, SE = 349.39) tasks, easy p = .014, η_p^2 = .21 , difficult p = .047, η_p^2 = .143.

MPE (H1.c): Mutual Co-Presence

There was no significant SVP x CVP difficulty interaction, for accuracy F(1, 26) = 1.79 , p = .192 , η_p^2 = .061, nor RT F(1, 26) = 0.51 , p = .482 , η_p^2 = .019.There was no significant PSS x CVP x SVP x difficulty interaction for accuracy, F(1, 26) = .33 , p = .57 , η_p^2 = .013. For RT there was a marginal SPP x CVP x SVP x difficulty interaction, F (1, 26) = 3.11, p = .089, η_p^2 = .107. Following up the marginal RT interaction, there was no significant contribution of CVP to SVP effect when SPP was off, for easy p = .174, η_p^2 = .070, nor difficult condition p = .71, η_p^2 = .006. The analysis demonstrates no supporting evidence that CVP contributes significantly to the MPE during video interaction.

Summary: MPE

There was not significant contribution of avatar companion visual presence (CVP) when measuring the MPE, rejecting ***H1.a*** that companions visual presence alone could be sufficient for MPE. There was an overall facilitation of performance both in accuracy (significant) and RT (marginal) when participants turned their self-visual presence (SVP) from off to on. There was no SFE related impact related just to SVP, not supporting the ***H1.b*** that self-presence of participant in the camera would lead to MPE related arousal. The performance speed improved on easy and difficult tasks when participants were seen through the video (SVP: on versus SVP: off) as they perform, and the companion could not monitor their performance (SPP: off). The participants improved in their performance accuracy on difficult tasks whilst being video present irrespective of monitoring. For easy participants performance accuracy only improved when the performance is not monitored (PSS: off) at the same time. There was no significant SFE contribution of co-presence (SVP x CVP), not supporting the ***H1.c*** that self and companion co-presence in video messenger would provide sufficient arousal for MPE. Overall, the SVP was facilitating irrespective of difficulty.

3.4.3 H2. Audience Effect (AE)

AE (H2.a): Performance Screen Sharing (PSS)

The analysis focused on testing whether the monitoring of performance alone, irrespective of other factors would contribute to the AE. The analysis revealed no significant PSS x difficulty interaction either for accuracy F (1, 26) = 1.68, p = .21, η_p^2 = .061, nor RT F (1, 26) = 1.72, p = .20, η_p^2 = .062. There was also no main effect of PSS, for accuracy F (1, 26) = 1.82, p = .19, η_p^2 = .065, or *RT*, F (1, 26) = .89, p = .35, η_p^2 = .033.

The planned follow up analyses of PSS, at each difficulty level separately, revealed that easy task was performed significantly faster when performance was monitored (PSS: on, M = 1366.67, SD = 290.31) versus not monitored (PSS: off, M = 1415.28, SD = 276.49), RT: p = .040, η_p^2 = .153. These RT finding replicates the avatar AE finding in experiment one. There were no other significant or marginal effects and no SFE relating to just performance screen-sharing.

AE (H2.b): Self-Present with Performance Sharing

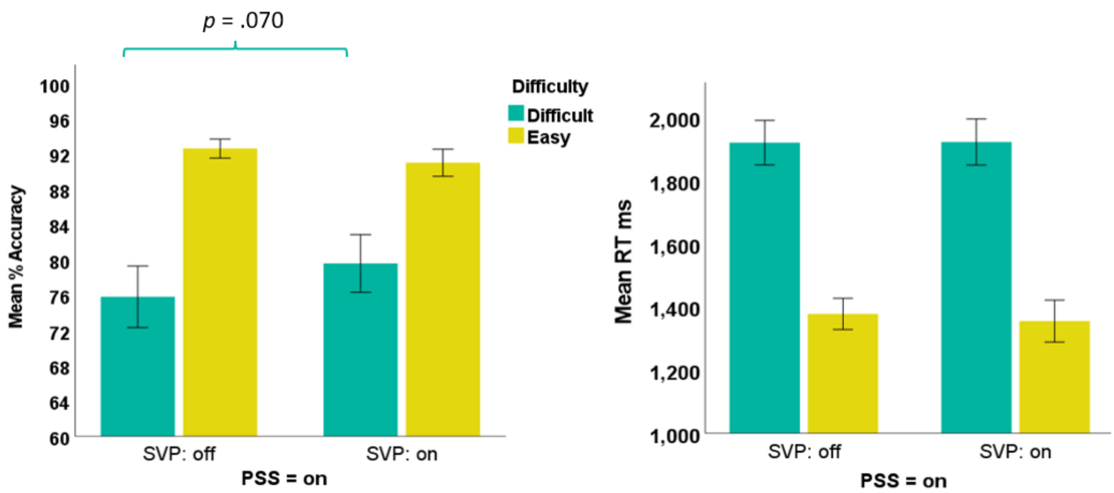
This analysis investigated whether being seen (SVP: off to SVP: on) whilst monitored would contribute additionally to the AE. As reported in the MPE results section above, there was a significant SPP x SVP x difficulty interaction for performance accuracy F (1, 26) = 6.5, p = .017, η_p^2 = .20, and none for RT F (1, 26) = .155, p = .70, η_p^2 = .006. There was also a marginal SPP x SVP interaction for RT F (1, 26) = 3.053, p = .092, η_p^2 = .105, none for accuracy F (1, 26) = 1.82, p = .189, η_p^2 = .065. In contrast to the MPE analyses above, where these interactions were investigated under condition of performance sharing off (PSS: off), for the AE, the SVP contrast are investigated under the condition when the participants are sharing their performance (PSS: on).

Accuracy. When PSS was turning the SVP on led to non-significant decrease in accuracy on easy condition (SVP: off M = 92.6, SD = 5.72, SVP: on M = 91.0, SD = 7.79), p = .41, η_p^2 = .027, and a marginal improvement on difficult task (SVP: off, M = 75.80, SD = 18.19, SVP: on, M = 79.60, SE = 17.15), p = .070, η_p^2 = .12, see **Figure 3.7.a.** There was no SFE based effect.

Reaction Times. For the RT the marginal SVP x SPP interaction was followed up, as planned, by breaking effects down by difficulty. Results showed no significant difference under the condition when performance screensharing was on (PSS: on) during monitoring, for easy (SVP: on, M = 1355.31, SE = 344.4, SVP: off, M = 1378.03, SE = 256.07), nor difficult tasks SVP: on, M = 1922.59, SD = 379.27, SVP: off, M = 1920.23, SD = 366.12), easy p = .51, η_p^2 = .017, difficult p = .96, η_p^2 < .001. see **Figure 3.7.b.**

Figure 3.7

Lack of Significant Self-Visual Presence (SVP) Facilitation When Performance Screen-Sharing.



a. Accuracy: SVP with PSS: on **b. RT:** SVP with PSS: on

Note. a significant facilitation of difficult task in (a) accuracy, and a marginal facilitation in performance speed (b) when participants self-camera was turned on (SVP: on) versus off (SVP: off).

AE:(H2.c) Mutual Co-Presence

As mentioned, MPE co-presence analysis above, there was no significant PSS x CVP x SVP x difficulty interaction for accuracy, F (1, 26) = .33, p = .57, η_p^2 = .013. For RT there was a marginal PSS x CVP x SVP x difficulty interaction, F (1, 26) = 3.11, p = .089, η_p^2 = .107. Following up the RT interaction for condition where PSS and SVP are on, there was no significant effect contribution of turning CVP off to on, for easy p = .13, η_p^2 = .088., and difficult p = .71, η_p^2 = .006. condition.

Summary: AE

Turning the performance monitoring on (from PSS: off to PSS: on) significantly increased participants performance speed on the easy task. There was no SFE, not supporting ***H2.a***, that performance monitoring alone elicits AE. The participants turning their video on (SVP: on) during performance monitoring, marginally improved the difficult task accuracy, difficult task accuracy being highest when participants were both monitored and seen. Turning self-video on (SVP: off to SVP: on) however dropped the performance accuracy for easy task numerically. There were no significant SFE of additional SVP during monitoring, not supporting ***H2.b***, that being seen whilst performance is monitoring gives rise to AE. The avatar companion visual presence (CVP) contribution to the AE was not significant, not supporting the hypothesis (***H2.c*)** that attentive avatar presence can be either motivating or distracting.

3.4.4 Post-Hoc: Easy Task SVP x SPP Relationship

Post-hoc analyses were conducted to further investigate the relationship of SVP x PSS for easy task, considering the observed potential reciprocal inhibition of SVP and PSS. The analysis was conducted only on the task accuracy, as it was justified given the significant SVP x PSS x difficulty interaction in accuracy, F (1, 26) = 6.5, p = .017, η_p^2 = .20. The data-driven prediction from the MPE and AE analyses was that for easy task the SVP and PSS might be mutually inhibitory, although facilitatory in isolation. Considering it was earlier tested (MPE: SVP) that turning SVP from off to on improved participants performance significantly only when PSS was off, the current analysis tested the reverse impact of whether turning screen-sharing from off to on when SVP is off is also facilitating. This prediction is indeed supported by the post-hoc exploratory analyses, Bonferroni corrected.

When SVP was off, turning from PSS: off to PSS: on significantly improved participants performance accuracy, p = .031, η_p^2 =. 167. Therefore, for easy performance accuracy either the PSS or SVP are significantly facilitating, when the other factor is off. This effect was not predicted by the original hypotheses and is not directly explained through the SFE.

3.5 Discussion

The current experiment investigated the MPE and AE within a video conference-based setting with a human-controlled avatar. To investigate the effects in greater depth, the study separated the effects into three factors: the self-video presence of the participant, the video presence of the participants' companion (avatar), and the performance presence of participants' task as it was shared to the companion. The effects of these factors were mapped onto the MPE and AE, in isolation and addition. The results of the predictions made are listed below.

There were three predictions related to MPE (H1). Hypothesis one (H1) predicted that the MPE can be elicited by the mere video presence of companion (H1.a; companion visual presence: CVP), the mere video presence of participants self (H1.b; self-visual presence: SVP), or alternatively an accumulation of the two presences, the co-presence (H1.c). The results showed that the only videoconference presence type which significantly impacted the participants task performance was self-visual presence (SVP). When participants self-camera was turned on, the performance was marginally faster and significantly more accurate overall. When breaking down effect by difficulty as per SFE, the difficult task accuracy improved significantly with turning SVP on, an effect found for MPE in experiment one. The easy task accuracy improved by turning SVP on, but only when the performance monitoring was turned off. Turning SVP on also facilitated easy task performance speed, and when controlled for monitoring being off, increased the speed also for difficult task alongside of easy. There was no significant effect of companion visual presence (CVP) either in isolation, or in accumulation with SVP. Therefore, it seems that mere presence-based task facilitation in the videoconference-based setting, similar effect reported in experiment one MPE, is driven by the self-visual presence of the participant in the social video context. The visual representation of videoconference-based human minded companion was not significantly impactful. There was no SFE idiosyncratic difficulty interaction found for any of the factors, self-visual presence impact was facilitatory.

Hypothesis two (H2) tested the AE as measure of performance screen-sharing (PSS), both in isolation and in combination of participants self-video presence (SVP) and the visibility of attentive avatar companion (through companion visual presence: CVP). The first part of this hypothesis (H2.a) predicted that the performance screen sharing (PSS) can elicit AE independently. To test this, the SVP levels (off and on) were contrasted at a level of performance screen-sharing being turned on (PSS: on). The results showed that turning screensharing (PSS: on) improved participants performance speed on the easy task, the same effect found in avatar companion group in experiment one during the AE analysis. However, as with experiment one, there was no SFE. Alternatively, to H2.a, H2.b predicted that AE is a factor of additive effect of performance screen-sharing and self-visual presence (H2.b; PSS × SVP). Being visually present when performance was monitored did not lead to any additional significant impacts for RT at any difficulty level. For accuracy, the results demonstrated that turning SVP on when monitored had an additional marginal facilitation for the difficult task performance. This accuracy performance outcome was numerically best of all the difficult conditions, possibly suggesting additive effects of PSS and SVP for difficult task. For the easy task accuracy, turning SVP on when task monitored numerically decreased task performance, an effect which seems to indicate a mediating nature of SVP when monitored (PSS: on). The final hypothesis of AE (H2.c) predicted that seeing avatars CVP would impact performance outcome when participants are monitored, due to either distraction or motivation. There was no significant effect of CVP. No SFE related interaction was found for any AE related analyses. The results showed that being performance monitored increases easy task performance overall, similarly, to being visually present, without the additive effect of SVP × PSS. The difficult task performance however does marginally improve when participant is both monitored and visually presence versus when not visually present, suggesting potential accumulation SVP × PSS.

To summarise, based on the current findings there was no MPE- or AE-related SFE found. The significant effect in this study showed that being merely self-present through a camera (SVP) improved difficult task performance accuracy and RT when the performance is not monitored. This effect is similar to the one found in the MPE analysis of experiment one. The easy task accuracy is facilitated by turning self-presence or task monitoring on, however not when both media are on together. The post-hoc analysis showing that SVP and PSS are reciprocally inhibiting. The easy task performance speed can be also improved through just performance monitoring or self-visual presence independently, but it seems that not additively. Therefore, it seems that the difficulty conditions seem to be impacted differently based on the social interaction (PSS, or SVP) levels occurring, however SVP is overall facilitating.

In the lack of SFE, it is challenging to associate the SVP observed in this study with implicit social arousal directly. It could be presumed that the performance speed would overall increase when the task is not seen by companion, because the participants would not be concerned over the accuracy of performance, rather indicating their competence by finishing task block faster as they are SVP seen. Therefore, it could be argued that this finding is just reflecting participants decision to trade off the task accuracy for speed, as accuracy is not monitored. If this was the case, it could be assumed that performance accuracy would drop, however there is no such evidence from the data. The SVP related task accuracy was facilitated even when the performance was not directly monitored (easy task), which could suggest that participants did experience socially motivated arousal irrespective of whether their performance is seen. Therefore, this performance improvement is not driven by the performance-based reputation management, nor merely performative speed for accuracy trade-off, but rather, an overall facilitation. It is possible that this facilitation is related to being social vigilant during self-exposure to the occluded companion, an effect resembling the state of vigilance in the MPE. Further testing is required to explore whether the same effects will occur when companion can be realistically seen, and whether companion mind-property (AI, human) changes the pattern of this effect.

Considering that the SVP presence effect overall replicated the finding of experiment one MPE, with no significant CVP impact, it is feasible that both the current experiment and the experiment one results are driven by the SVP of the participant, irrespective of companion. It is possible that in the case of videoconference-based co-presence, when participant and companion do not share a mutual space, the visual representation of companion is irrelevant, as long as participants feel virtually exposed to someone in the videoconference-based setting. This prediction requires replication under the presence of non-human minded companion, such as AI-agent, and performing on camera alone without a companion.

Additionally, to the impact of mere self-visual presence, the current finding revealed that task difficulty impact could depend on the level of self-exposure (PSS, or SVP). The difficult task improvement is mostly driven by SVP, however easy task impact seems more complex relying on SVP × PSS interaction. This impact pattern of on easy task performance could explain why there was no significant MPE effect found for the easy task accuracy in experiment one. As in experiment one, when co-present with companion, from the participant point of view their SVP and PSS were always on together, irrespective of whether the companion was watching or not. Although this relationship is not entirely clear, it seems that being video present and sharing performance simultaneously when both media channels are exposed equally cancels the easy task facilitation out. However, if only one media channel is exposed to companion seems to be facilitatory. One possible explanation could be that because the easy task performance requires less effort, the participant have more time to focus on their visual appearance when SVP is on, especially when monitored, which could be distracting. When only one of the media channels is on, the participant just focusses on the task or SVP, without distraction to both channels, which is facilitating. This could be because the easy task is more performative, as participants know they are doing well and might be interested in portraying this competent image as they do. In contrast to easy task, the difficult task is more cognitively taxing, participants pay more attention to the task, rather than towards the performative performance and self-image, being merely facilitated though the sense of self-presence. It is challenging to prove this level of attention shifts without eye tracking or other physiological measures. However, it is worth noting that the video conference-based setting is unique, in contrast to the real word, due to the participants ability to see themselves performing through camera. It is possible that this level of self-presence might interact with SFE factors in ways often not considered in the real-world communication.

Interestingly we found the same AE for easy performance speed increase as in experiment one. However, the results of AE analysis did not support the H2.c that this could be due to avatar unique companion visual presence. There was also no overall significant impact of whether the avatar companion was visually present or not. The finding goes against the prediction that virtual human presence can be either distracting or motivating. The finding also contradicts the literature in which virtual companion is often impactful. However, arguably, most of the literature testing human to virtual human interaction does not parse the level of participants self-presence when investigating the effects. Therefore, it is possible that at least some companion impact effects, reported in prior video companion studies, could have been driven merely by the participants self-presence in the experiment, rather than the companion directed cognition. This assumption should be tested further with similar paradigms and with different companions.

One of the other possible explanations, of why companion driven co-presence effect was not impactful in this experiment, could be the videoconference medium itself. In experiment one and two of this thesis, the sufficient co-presence was predicted to be established remotely through visual interactive presence, e.g., the participants ability to see their virtual companion and to acknowledge the companion's ability to see the participant back. The current study finding could suggest that, at least in video co-presence, this level of two-dimensional video co-presence is not sufficient to be impactful. Therefore, it seems that during a video-based interaction, where the experience of physical co-presence is limited, the interpersonal distance could be amplified by the media itself. This could be due to participants clearly being able to draw the line between their own environment and their companion's environment, by seeing the companion in a physically different space though video window. This could also be the reason why the companions in the immersive spaces are more impactful overall, even to extend of lowering the impact difference between the agent and avatar impact (meta-analysis: (Fox et al., 2015). Research does seem to suggest that the perceived physical co-presence can be simulated though higher virtual immersion. Therefore, theoretically, it is possible to amplify the CVP impact by heightening the immersive co-presence, simulating a more co-immersive presence experience. However, whether the heightened immersion with companion is sufficient to elicit SFE, even when sacrificing the realism of visual self to immersive space, is to be explored. The next chapter focuses on testing the effects of virtual AI and human minded virtual companions at different level of humanness and co-presence impact.

Chapter 4: Experiment Three

The impact of Appearance and Mindedness on MPE and AE in an Immersive Social Virtual Reality

The impact of Appearance and Mindedness on MPE and AE in an Immersive Social Virtual Reality

4.1 Introduction

The first two experiments in this thesis tested social facilitation effects (SFE) in an online video conference-based setting. The findings overall suggested that being visually self-present in the video, facilitated the participant's performance. The results, on whether the visual presence of the companion contributes to the participant's performance changes, surprisingly demonstrated no significant contribution. As discussed in the previous chapter, one of the reasons, why the companion's visual presence might not have been impactful, could be the lack of a perceived sense of mutual physical co-presence between the participant and their companion. It is possible that this level of perceived co-presence cannot be attained through a video – a medium that potentially amplifies the distance between the companion environmental contexts.

The urge to evoke a higher sense of virtual co-presence remotely is one of the main reasons why certain entertainment and social-media companies have high stakes in more immersive and augmented technologies, in which the user can feel that they are in the same virtual environment with others. Similarly, to in-real-world interaction between people, the simulated virtual co-presence within the immersive virtual environments seems to be on more equal interactive terms between the virtual companions. For example, within the immersive space, a virtual companion can directly approach the virtual participant and physically engage with the participant's embodied representation in that virtual space. The sense of perceived interpersonal physical co-presence in immersive space is well illustrated in (Bailenson et al., 2003) study on interpersonal proximity. The study demonstrated that during the virtually immersed interaction, the participants resulted in maintaining interpersonal distance from the virtual agent, similarly to how the distance would be maintained between people in an in-real-world situation. This finding was irrespective of whether the virtual companion was AI or human-driven, suggesting that the companion visual co-presence itself drove the participant's behavioural change. This level of virtually mediated perceived physical interaction is categorically different from the video interaction, in which the video companion has no physical impact on the participant or their environment. With the meta-analysis investigating virtual companion impact of immersive and desktop-based virtual companionship, reporting that higher immersion with companion is more impactful, the immersive co-presence of companion bringing the impact of visually co-present AI-agents and avatars closer (Fox et al., 2014). Although overall it is predicted that the avatars should be overall more impactful due to their mentalising property (Blascovich, 2002), whether the effect reported in Bailenson et al., (2003) study (above) was merely reflexive or significantly socially stimulating for the participant (such as the MPE) is not directly measured in their study, however this finding is an important milestone in understanding more about perceived presence in emerging immersive virtual social environment.

Given the growing interest in immersive social virtual reality over the last decade, there are already studies which tested SFE during immersive experiences. The findings are mixed, with results suggesting both facilitation (Park &

Catrambone, 2007) and inhibition (Zanbaka et al., 2007). The mixed findings make it challenging to draw any concrete conclusions, especially considering these studies often report a general SFE impact, without investigating the underlying mechanisms that drive the effect. However, as argues throughout this thesis, considering the precise context in which the effect occurred and how the participants perceived the interaction is important. As it has been demonstrated in the previous two experiment in this thesis, the two SFE based effect – the MPE and AE, although similar in outcome, are elicited through different cognitive mechanisms. It is possible that not accounting for these SFE mechanisms contributed to the discrepancy in the previous reports looking into virtual social facilitation.

To the author's knowledge, there has not yet been a systematic immersive virtual reality testing accounting for the mechanisms underlying the two effects associated with SFE, the MPE and the AE based on their underlying social mechanisms. For MPE, the mechanism (MPE-m) is being co-present with another person in the environment, for AE, the mechanism (AE-m) is being monitored by another person. With the current increasing use of immersive social platforms, it is important to understand which elements of these virtual social experiences have the most impact on user performance and whether this impact is positive or negative. Knowing these effects will help develop further considerations on how to benefit the users depending on their immersive experience goals, e.g., education, training, well-being or entertainment. Besides the industry utility of these findings, testing within the immersive co-present reality can reveal additional details of human social cognition. For example, in contrast to the video-based experimental manipulation, which is merely a visual companion presence, the immersive environment paradigm can test the perceived sense of co-presence in the same virtual environment. Testing the perception of mutual presence, without physical co-presence, is also a challenge in the in-real-world situation. Therefore, immersive social platforms offer a unique opportunity to test the perceived sense of co-presence through immersive simulation, with a high degree of control over the co-presence levels of interest.

The current experiment uses immersive virtual reality to disentangle the cognitive mechanisms of SFE. As per the previous two experiments, this experiment aims to systematically vary and test the contributing factors which might influence the participant's cognitive performance outcomes depending on their perceived social interaction. Similarly, to the previous two experiments, the current experiment tests the AE and MPE through their hypothesises mechanism (AE-m and MPE-m), and the overall impact of the social context in which participants perform. To do this, the paradigm applies the same logic of parsing the virtual mind and the body of the interacting individuals whilst testing their individual effect (see **Chapter 1: The Parsing of Virtual Mind and Body Presence)**, as with prior two experiments.

In the current immersive experiment (experiment three) the participants performed the same cognitive task, as with the previous two experiments, the relational reasoning paradigm (RRP). However, in this paradigm the task is projected onto the large TV-screen wall mounted within a virtual immersive room. The screen in the immersive environment is positioned with consideration that both the participant and their companion can see the task screen. The companion, if they are visually present, are sitting between the participant and their screen.

Therefore, the companion can visually monitor both at the performing participant and their performance, however the companion can also be also glimpsed at by the participant. The participant can see the companion in peripheral vision when focusing on performing the task. This is done to assure the uncertainty over companions' precise behaviours when participant is pre-occupied with the task (as per MPE: Bernard Guerin, 1983, 1986), but to enables participants the ability to visually engage with companions' presence if they feel compelled to do so. Considering that participants cannot attend to both the task and companion simultaneously, the participant needs to visually disengage from the task, to gaze at their companion (suggesting distraction). Otherwise, the participant will have to perform in the state of uncertainty of virtual other, suggesting MPE. Throughout the task performance, the participants are told that they are testing a virtual marking platform, and the companion will, at times, attentively monitor them performing. During attentive monitoring, if the companion is visually present, they randomly turn towards the participant or their performance, indicating monitoring. When not monitoring, the visually present companion looks down, disengaging with participant and their task performance.

To test the contribution of a companion's visual presence (CVP) within an immersive environment, similar to experiment two, the current experiment tests whether performing under the companions' co-immersive visual presence significantly impacts the participant's cognitive performance. The companion's visually present (CVP: present) condition is contrasted to a condition in which participants perform without seeing their companion in the same virtual space (CVP: none). Importantly, this approach will test whether the present companion impact is driven by the mere distraction of companions' presence in the environment (performance drops; similarly, to Zanbaka et al., (2007) or higher social arousal, as measured in MPE (facilitation of easier tasks, inhibition of more difficult tasks). Furthermore, the study tests whether the type of companion's visual presence contributes additionally to the effect. An extensive review on virtual social interaction by Oh et al., (2018) highlights that both non-humanoid and humanoid virtual companion's presence affects participant's behaviour within immersive spaces, in contrast to a virtual companion that is not visually present.

The growing evidence, however, suggests that the companion visual type might be important, especially for a companion which is driven by an artificial intelligence, such as AI agent, rather than another person, such as avatar. The theories, such as the threshold model of social influence (Blascovich, 2002) and ethopoeia (Nass et al., 1994; Nass & Moon, 2000) agree that the visual humanoid properties of machine run mechanisms (robots, computers) or characters (virtual agents) facilitate the socially motivated processing towards this social object. Both theories explain this process as a social heuristic, that helps people adapt to a novel social interaction, by applying a social schema used in similar situations in the real world to human looking companions. Studies testing these theories, such as those (Appel et al., 2012; Von Der Pütten et al., 2010), report that the type of companion visual presence is important, and humanoid companion form is indeed more impactful than the non-humanoid visual companion. The study by Von Der Pütten et al., (2010) also reporting that the humanoid companion form within an immersive setting can possibly overwrite the impact of companion's agency (i.e., who is running the companion, human or an AI), which is often believed to be of the highest level of impact as per the threshold model of social influence. Therefore, it is possible that any companion visual presence, versus none companion visual presence, will impact the participant's performance significantly, however the humanoid presence type will be the most impactful. To test these assumptions, firstly both the non-humanoid and the humanoid companion visual presence types will be merged into one group's (CVP: present) first, testing the cognitive performance outcomes against the group with no visually present companion (CVP: none), irrespective of companion presence type. Then, in secondary analyses, all the companion visual presence types will be contrasted with one another (CVP: non-humanoid, versus CVP: humanoid) and with when companion visual presence is none (CVP: none).

In addition to testing the MPE impact of CVP and the contribution of their humanoid form, this study will test the effect of performance monitoring (AE) in the immersive space. Unlike the MPE, which is believed to be driven by the sense of co-presence with the companion, and possibly the companion visual type, the AE is believed to be reliant on the potential judgement expected from another person, but not an AI. Therefore, the main contrast of AE, similarly to the previous two experiments, will be drawn between the attentive monitoring and not monitoring conditions, investigating the effect based on the companion's agency. The monitoring will be contrasted to the not monitoring conditions, at each level of companion agency (AI driven, or human-driven). All companion visual presence participants groups will perform under the monitoring versus not monitoring conditions, The start and end of monitoring conditions will be explicitly stated on the TV-task screen withing the IVE, making sure participants do not misinterpret the condition block. In addition, to testing whether the monitoring is driven by human-driven companion agency, an additional analysis will be conducted to investigate whether the companion presence type contributes to the effect.

With AE, it is mostly assumed that the companion visual presence is irrelevant, considering that the effect can be elicited when participants are merely cued with a monitoring signal (Dumonheil, 2016). However, as found in experiment one, the companion visual form can influence how the AE impacts the participant's performance, the AE performance trajectory different in real human and avatar companion presence. Based on (Blascovich, 2002) model of virtual social influence, the companion’s presence, especially humanlike, can boost the social influence of virtual others. If so, it is possible that the monitoring companion's presence, especially in a humanoid form, might contribute additionally to the AE, as it reflects where the companion might be looking when the monitoring occurs. It is however unclear, whether the visual presence of the monitoring companion will be facilitating or distracting. Therefore, additionally to the main effect of monitoring, the current study explores how the companion’s visual presence affects the participant’s performance when they are monitored.

Both the MPE and AE inside the immersive environment are of course dependent on whether the participants themselves feel that they are part of the shared immersive virtual environment. As with any type of testing with novel technologies, testing in immersive environment has its limitations. In contrast to the video-based experiments reported earlier in this thesis, the participant's self-presence in immersive virtual reality is not as clearly established. During video presence, the participants are their own embodied realistic selves, in their own environment, broadcasting online. In immersive interaction they are currently represented as virtual avatars or non-embodied observers. This, of course, creates a challenge when testing for an effect, which relies on self-presence, or self-visual presence, such as the SFE.

One of the most reliable effects in the two video-based experiments reported in this thesis was the MPE based facilitation. This facilitation was potentially mainly driven by the video self-visual presence of the participant, as demonstrated in the second experiment (factor SVP). Concluding from studies reporting on the importance of self-visual presence in self-referential processing online (Teng, 2017; Tseng et al., 2015) and our own results, it seems that when testing for any SFE, the degree of self-presence should not be ignored. However, one of the main challenges in testing with immersive virtual reality, whilst accounting for reliable self-presence, is that throughout the study, the participants are aware that they are wearing a head-mounted display and therefore their realistic self (face, emotions, body motion) is not exposed. Therefore, the participant might perceive themselves as a merely passive observer within the shared immersive environment, rather than an active virtual embodied presence that reflects their facial expressions and gazes in real-time. Unfortunately, at the time when the experiment was conducted, the technology of photorealistic self-visual presence in IVE was yet to be developed by immersive technology providers.

The experimental design in this study acknowledges the limitation of realistic self-representation in immersive space and attempts to account for the possible confounds inflicted by hardware and software constraints at the time of testing. To overcome the head-mounted display occlusion of perceived self, the participants had to believe that their self-presence is meaningful and identifiable within the immersive shared environment. This step is important, as self-identification is reported to lead to more prosocial responses, and accountability even in online situations when participants cannot be seen (Teng, 2017). Using a generalised user avatar was considered a sub-optimal strategy for this study, as multiple research reports that being embodied in an avatar body, that does not match own, can alter a participant's behaviour (Banakou et al., 2013; Peck et al., 2013) and self-referential disposition (Kim & Sundar, 2012). Therefore, the self-presence of the participant in this study was not elicited through a generalised self-avatar, but rather the participant's belief of what the companion could observe about the participant as they perform in the same immersive world. In this experiment, there were two steps in making sure the participants feel more self-conscious and co-present with their co-immersed companion. Firstly, before starting the study, and prior to putting on the virtual head-mounted display, the participants are greeted by the researcher in person. Establishing that it is known that it is they who will be performing in immersive space and being monitored in real-time. Secondly, the participants are told that their companion (human-or AI-minded) can see their gaze behaviour and head motion as they perform, as well as their performance. Specifically, the participants are led to believe that their companion can see where participants are looking as they perform, for example around the room, at the companion or towards the task screen, and when they are not paying attention. To makes sure the participants believe this cover story, they are told that there are inbuilt eye trackers in the headset. Throughout the study, the participants are led to believe that they are testing a new performance evaluation software and the attention shifts measures were for a companion to understand(human-minded)/process (AI-minded) how well the participants focus on the task. The experimental findings from the real-world interactions suggest that this type of functional self-visual presence could be sufficient to establish behavioural change and make participants more self-conscious in their environment. For example, when the participants are wearing an eye-tracking device their behaviours switch to more pro-social (Wong & Stephen, 2019) and when participating in brain imaging studies thinking their brain data could be interpreted as they perform changes in the social brain regions (Turner et al., 2020). At the end of the study, the participants are debriefed and quizzed on whether they believed the cover story.

This self-visual presence manipulation was essential to heighten the participant's perceived agency and sense of observable self within the immersive mutual space, to test the MPE of co-presence and the AE. The participant should perceive themselves as a self-present protagonist throughout the study. If there is no reliable self-representation in the environment, arguably, there could be no facilitative effects of monitoring (AE), nor potentially co-presence based MPE facilitation. For example, without reliable self-presence in the environment, there is no sufficient foundation for the AE to occur, considering that the participants cannot be monitored if they are not present. This is of course, unless the sharing performance independently elicits the AE, which did not seem to be the case in experiment two.

Whether there could be a sufficient MPE, without a realistic sense of self-presence is to be established as well. As argued in the experiment two, for the co-presence related MPE to emerge, the participation should also feel that they are sharing the same environment with their companion in a tangible way. The ability to merely observe a virtual companion whilst being immersed in the same virtual space, without having realistic embodied self-visual presence, could be potentially sufficient to elicit sense of co-presence. The effect could be simulated through the sense immersive co-presence and the uncertainly of the co-immersed entity in the same room. However, whether this level of co-presence, without realistic self-visual presence, is significant for the vigilance based second person social excitation, is going to be tested in this study. Arguably, similarly to the AE, there could be no MPE without sufficient self-visual presence, as the companion visual presence (CVP) without sufficient self-visual presence could be potentially perceived as the participant observing their companion (the effect being merely inhibitory through distraction), without demonstrating any second-person cognition of co-presence related response, such as anticipated through MPE.

There are several predictions made based on the factors presented above. The experimental design consisting of four factors Companion Agency (human, AI), Companion Visual Presence (none, non-humanoid, humanoid), Monitoring (Monitored, Not Monitored) and Difficulty (Easy, Difficulty) as measured by relational reasoning paradigm (RRP). See **Figure 4.1** below for diagram illustrating the summary of factors and their corresponding levels in the current experimental design.

Figure 4.1

The Schematic of Independent Variables and Corresponding Levels in Experiment Three.

Experiment Three: Design Summary

IV 1: Between-Subjects	**IV 2:** Between-Subjects	**IV 2:** Within-Subjects	**IV 3:** Within-Subjects
Companion Agency	**Companion Visual Presence**	**Monitoring**	**Difficulty**
AI Human	None Non-Humanoid Humanoid	Monitoring Not Monitoring	Easy Difficult

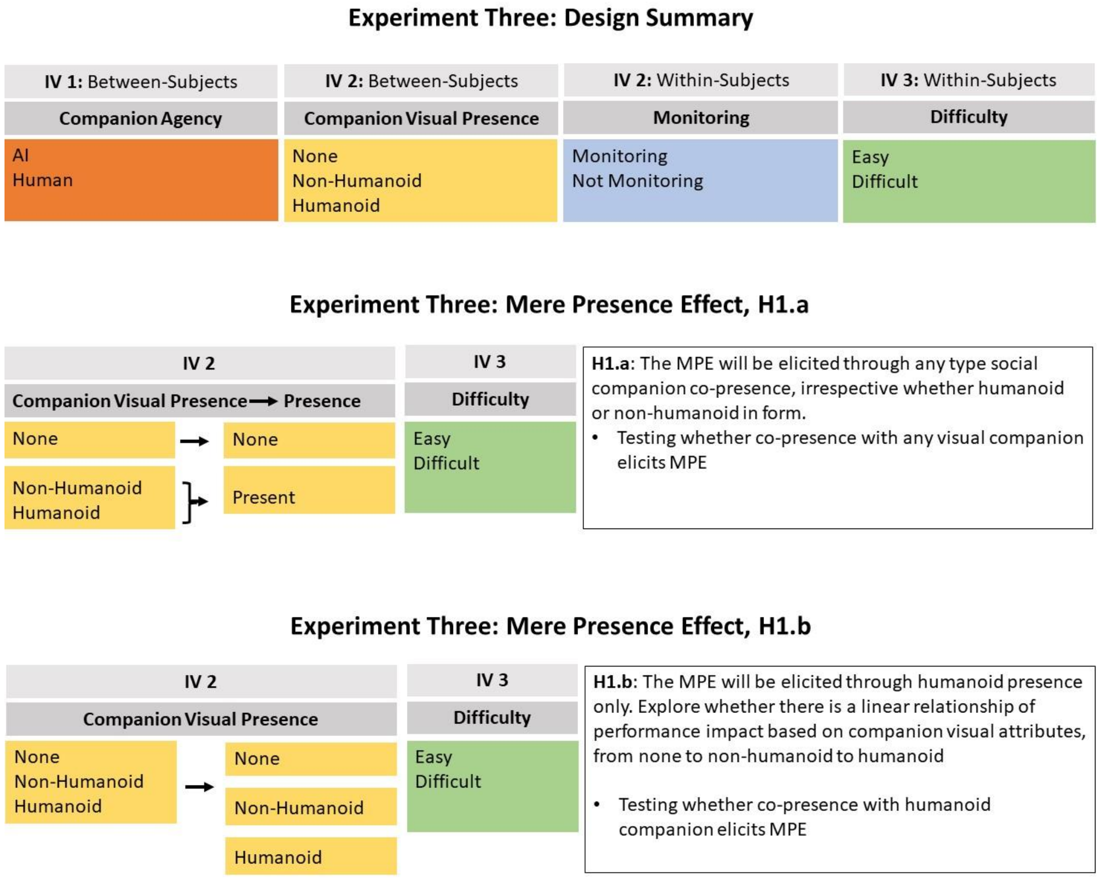
DV 1: Accuracy (%), **DV 2:** Reaction Times (ms) per accurate responses only
SFE: Better performance on easy and worse on difficult tasks, when in social context versus when not.

Prior to testing the SFE based predictions, a baseline main effect of difficulty is investigated. As with prior two experiments, the main effect of difficulty is expected to result in a significant difference between easy and difficult trials, with performance on easy trials expected to be performed faster and more accurate. The predictions are listed below.

Hypothesis One (H1): The Mere Presence Effect (MPE). The first SFE based analysis tests the MPE, through the relation between companion visual presence (CVP) and task difficulty (CVP x difficulty). There are two hypotheses relating to the immersive MPE. See **Figure 4.2** below for diagram illustrating the summary of factors and their corresponding levels in the current experimental design and their analysis mapping onto the two MPE hypotheses proposed in the Experiment three of this thesis. The diagrams are followed by the two MPE hypothesis set up in the current experiment.

Figure 4.2

The Schematic of Independent Variable Mapping onto the MPE Analysis in Experiment Three.



Hypothesis one (***H1.a***) predicts that any companion presence irrespective of its type (CVP: non-humanoid or CVP: humanoid) will elicit MPE, in contrast to when the companion visual presence is none (CVP: none). The hypothesis is tested by contrasting a combined condition named CVP: Present (CVP: non-humanoid or CVP: humanoid combined) versus the condition of visually absent companion, the CVP: none. If immersive MPE, CVP: present versus CVP: none, is socially arousing as per SFE, the participant's performance on easy tasks should improve and difficult task performance should decline, when companion is visually co-present with participant.

The second hypothesis of MPE (***H1.b***) predicts that the MPE will be affected more by the humanlike companion presence than non-humanoid presence or none, easy and difficult condition affected linearly as the social influence increases (as per (Blascovich, 2002). The ***H1.b*** will be supported if the performance on easy condition will improve, and decrease on difficult condition, linearly as the CVP level of social influence increases, with CVP: none being lowest, CVP: non-humanoid in middle, and CVP: humanoid presence being of highest influence. The hypothesis is tested by contrasting the three levels of CVP (none, non-humanoid, humanoid) with one-another. Similarly, to the first analysis, the effects are analysed at each level of task difficulty.

Hypothesis Two (H2): The Audience Effect (AE). The second part of the analysis focuses on the AE in immersive environment, investigating whether AE in co-immersive social environment can be elicited through monitoring, and whether the effect will be driven by a human-minded companion (companion agency: human) but not an AI-minded companion (companion agency: AI). To test this, the monitoring versus not monitoring condition is contrasted per each level of companion agency (AI, human) separately. To assure the effects are in accordance with the SFE, the analysis is run for easy and difficult conditions separately, expecting better performance on easy and worse on difficult tasks, when monitored versus not monitored. See **Figure 4.3** below for diagram illustrating the summary of factors and their corresponding levels in the current experimental design and their analysis mapping onto the two MPE hypotheses proposed in the Experiment three of this thesis. The diagrams are followed by the two AE hypothesis set up in the current experiment.

Figure 4.3

The Schematic of Independent Variable Mapping onto the AE Analysis in Experiment Three.

Experiment Three: Design Summary

IV 1: Between-Subjects	**IV 2:** Between-Subjects	**IV 2:** Within-Subjects	**IV 3:** Within-Subjects
Companion Agency	**Companion Visual Presence**	**Monitoring**	**Difficulty**
AI Human	None Non-Humanoid Humanoid	Monitoring Not Monitoring	Easy Difficult

Experiment Three: Audience Effect, H2.a

IV 1	**IV 2**	**IV 3**
Companion Agency	**Monitoring**	**Difficulty**
AI Human	Monitoring Not Monitoring	Easy Difficult

H2.a: The AE will be elicited through monitoring by a human minded companion (companion agency: human), not AI. Tested within AI and Human companion agency groups separately, irrespective of Companion Visual Presence.

- Testing whether monitoring by a human minded companion will elicit AE in an immersive virtual space

Experiment Three: Audience Effect, H2.b

IV 1	**IV 2**	**IV 2**	**IV 3**
Companion Agency	**Monitoring**	**Companion Visual Presence**	**Difficulty**
Human	Monitoring	None Non-Humanoid Humanoid	Easy Difficult

H2.b: The companion visual presence will contribute additionally to the AE in human minded companion (companion agency: human), impacting linearly with lowest impact in none, then non-humanoid, and highest in humanoid from.

- Testing whether companion visual presence contributes additionally to AE

The AE related ***H2.a*** predicts that participants cognitive performance will change according to SFE when monitored versus when not, and the effect will be present in human-minded companion agency, but not AI, participants groups.

Alongside the main impact of AE based on companion agency, an additional analysis is conducted to test the contribution of companion visual presence (CVP) type to the AE. The prediction of companion visual type (CVP: none, non-humanoid, humanoid) impact differences during the AE are made deriving from (Blascovich, 2002) social influence model mentioned above. The ***H2.b***, relating to AE contribution of CVP, predicts that, a linear performance impact relating to higher companion humanness in CVP (from none to non-humanoid to humanoid), would result in the higher companion social influence in observed AE. The effects are explored per difficulty and easy conditions separately.

Hypothesis Three (H3): Social Context Effect. Additionally, to the SFE based analyses, the overall context effects (similar to experiment one) will be investigated to explore whether overall anticipation of performing under a human-minded or AI-minded companion changes participant's performance. This will be explored both irrespective of CVP and with CVP in the model. In the experiment one social context effect, the participants performed overall worse under the companion at the highest social influence level as per the Blascovich (2002) social influence model, with the human-minded real-human companion group performing the worst and the artificial AI companion the best. The effect was attributed to the evaluation anxiety based on the perceived social influence levels, in experiment one. Therefore, the social context effects hypothesis (**H3.a**) predicts that, if performing in immersive reality is affected by the evaluation anxiety, there should be an overall worst performance in the human companion agency group. Additionally, the ***H2.b*** predicts that due to highest social influence of humanoid companion, the performance will be worst overall when the CVP is the present humanoid companion condition. This hypothesis is tested for companion agency separately, and then as companion agency × CVP interaction. The companion agency × CVP interaction is tested as contrast of AI vs human agency difference per each CVP level.

4.2 Methods

4.2.1 Design

The experiment relied on a four-way 2 x 3 x 2 x 2 mixed design, with two between-subjects variables, Companion Agency (AI, Human) and Companion Visual Presence (None, Non-Humanoid, Humanoid), and two within subject's factors, the level of Monitoring (Monitored, Not Monitored) under which participants performed, and task Difficulty (Easy, Difficult). The task used was the same Relational Reasoning Paradigm (RRP) that was used in the earlier chapters, measuring per cent accuracy and reaction times (RT) per accurate responses only. Participants who performed under fifty per cent accuracy for Easy and Difficult conditions combined or performed more than 3 SD away from the mean, were removed from the final analysis.

4.2.2 Participants

The final data analysis consisted of 103 participants, 73 female and 30 males, with the age range of 18-55 (M = 26.23, SD = 7.23). A total of 138 participants were recruited to take part in the study, aiming to enter 18 participants per group for analysis. The group sample size was powered (G*Power) at $1\text{-}\beta = .8$, $\alpha = .05$, Cohen $f = .44$, as per (Dumontheil et al., 2016) Task 2 x Audience 2 interaction. A total of 35 participants were removed from the data analysis, for either not following the study instructions or due to their accuracy performance both on easy and difficult tasks combined falling under 50 per cent. Out of the 35, 19 participants were removed for not believing the experimental manipulation of monitoring or the companion agency (mind AI or human).

There was no prior experience in IVE required to take part in the study. The simulation sickness risk was considered low, due to the stationary nature of the experiment and as a result of piloting the study on participants with a higher simulation sickness quotient (as measured by the Motion Sickness Susceptibility Questionnaire, MSSQ-Short(Golding, 2006), reporting no discomfort. The participants were reimbursed with either course credits or monetarily, and fully debriefed on the social manipulation script after the completion of the experiment. The study was approved by Birkbeck, University of London, Ethics Committee: 181933.

4.2.3 Virtual Environment

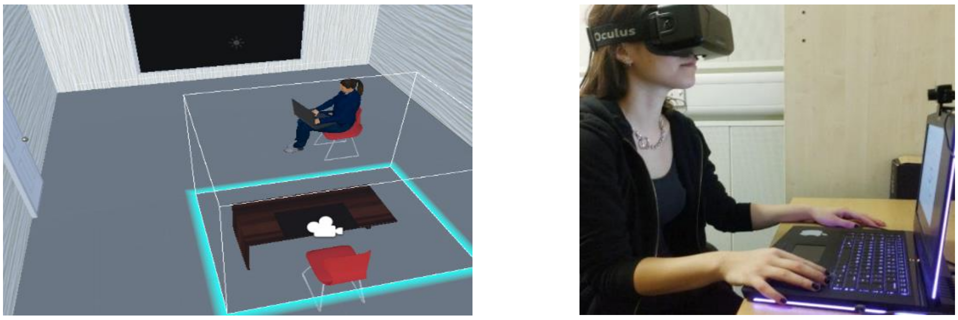
The Immersive Virtual Environment (IVE) comprised of a brightly lit room with textured white walls, a desk with a chair, and a large flat TV screen on which the stimuli were presented (aerial virtual room perspective in **Figure 4.4, a**).

The participants sat behind the virtual desk inside the environment, facing the TV screen positioned on the wall in front of the participant. In the real-world lab cubicle, the participant sat behind the computer wearing an Oculus HMD (**Figure 3.1, b**), pressing the keys on the keyboard, responding yes (right arrow click) or no (left arrow click) on the RRP task.

Depending on the experimental group assigned, the virtual companion was present in either a non-humanoid social presence form (observing interactive camera, **Figure 4.5, a**), humanoid form (an interactive humanoid character, **Figure 4.5, *b***), or visually non-present companion (companions animated presence replaced by an animated office fan, **Figure 4.5, c**). All virtual objects were positioned ensuring the participants can fully observe the task on a virtual TV screen, but also notice any movement by the companion, or the non-social animated object (e.g., camera or fan), see **Figure 4.5. c***,* for objects placement within IVE (example with a humanoid companion present).

Figure 4.4

Virtual Environment Object Placement and Real-World Participant Positioning.

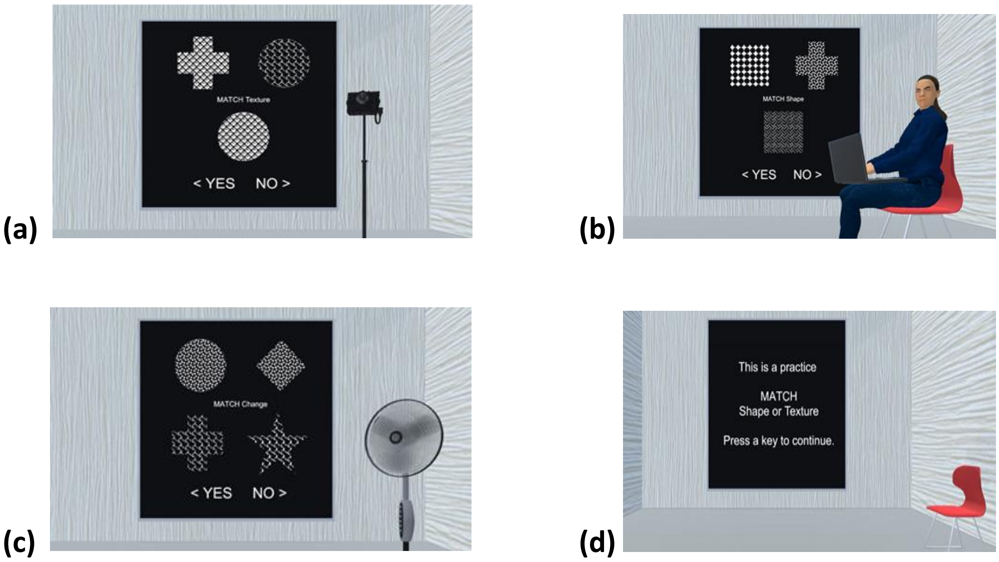


(a) **(b)**

Note. **(a)** Top-down views of the virtual environment are set up from the perspective of the Unity game engine. The participants' desk was positioned at the back of the virtual room. The camera icon highlights the participant's positioning behind the virtual table inside the IVE. **(b)** A participant taking part in the study wearing Oculus Rift HMD using a virtual reality compatible laptop.

Figure 4.5

The Companion Observing Presence Conditions from the Participants Perspective in IVE.



Note. The virtual environment setup from the participants' perspective, displaying the companions and the TV screen with the stimuli**. a.** A present non-humanoid condition in which the participant believed that they were monitored through an interactive controlled virtual camera. **b**. The humanoid presence condition, in which the participant believed they were monitored through the gaze of the humanoid character. **c.** companion visually absent (none) condition, during which participants believed they could be monitored by either an AI or human, however without being able to see the companion. **d.** The IVE layout of a practice session environment when no interactive objects were present.

4.2.4 Social Context Script

Similarly, to the online video experiments in the earlier chapters, the participants in the current study were led to believe that they are testing virtual monitoring and tracking software and that at some point during the task they will be monitored in real-time by either an AI algorithm or a real human observer. The participants believed that their gazing behaviour (as projected through a VR headset) and performance was monitored by either another person (human mind) or an automated algorithm (AI processing). The companion monitoring blocks were marked by an IVE onscreen instruction "you are now being watched", which was then followed by the companion's monitoring behaviour as the participants performed the task. After the study's completion, all participants were asked whether they believed their companion was congruent with the manipulation. Contrary to the participant's belief, the social companion presence and monitoring behaviours within the IVE were all automated and matched across all the companion groups. There was no virtual real-time monitoring occurring at any time throughout the study by either companion. After the debriefing procedure revealed the social manipulation, the participants had a choice of withdrawing or committing their data to the analysis. Only the participants who consented to data inclusion and who believed in the social context script were included in the final analysis.

4.2.5 Companion's Social Presence and Monitoring

Depending on the group assigned, the companions' visual presence within IVE was either socially meaningful, i.e., a humanoid character or non-humanoid camera, or lacked socially meaningful presence, i.e., an animated office fan with no visible social presence value. The monitored and not monitored condition blocks were initiated by instructions on the IVE TV task screen ("You are now being watched"," You are now not being watched "). During the training session, the participants performed alongside a placeholder for the companion's visual presence in the study. The companion location placeholder during training sessions was substituted with a stationary chair (**Figure 4.5, d**) for all groups.

Companion Visually Present: non-humanoid and humanoid

During the testing sessions, there were two socially meaningful companion visual presence (CVP)conditions, the non-humanoid and humanoid present companion. For the non-humanoid presence, the social companion presence was expressed in a form of an interactive camera on a tripod (**Figure 4.5, a**), which participants believed to be real-time operated by either a monitoring real person or by an autonomous AI algorithm. Participants believed that the companion, AI or human depending on the companion agency group, could monitor them inside the IVE using the camera (virtual CCTV). For the humanoid presence condition, the companion was a humanoid virtual companion (**Figure 4.5, b**), believed to also controlled by the companion in the real world, similarly to the non-humanoid companion condition. For both companions visually present conditions, the participants believed that a real-world companion (AI, or human) could see into the IVE from the perspective of the virtual companion (either lens: non-humanoid camera, or gaze: humanoid).

During the monitoring conditions, both the AI and human companion representations in the visually present groups (non-humanoid, humanoid) were animated to simulate monitoring motion, ranging between looking toward the participant and to the main task screen, as the participants performed. Both the non-humanoid and the humanoid companions gazing motion was synchronised in a way that the head-turn towards and away from a participant in the humanoid character condition, would occur at the same time and for the same duration as the camera turn on the tripod, during all trials. In the not monitored condition, the non-humanoid camera and the humanoid character's head tilted down and remained facing down throughout the condition block, with no observation motion directed towards the participant. To assure a more natural not monitoring condition, in the case of humanoid character conditions, the character was looking down into their laptop.

Companion Visual Presence: None

During testing session, the groups with no visually present companion (companion visual presence: none) performed seemingly alone, with the only moving object in the immersive environment being an office fan. The participants believed that the office fan (**Figure 4.5, c**), experimentally used as a replacement for a social agent, was just part of the environment and operated independently from the monitoring conditions. There was no visually meaningful companion presence within the immersive space from the participants perspective. The placement of the office fan was required to establish that participants are indeed socially motivated (distracted) by a social object (visually present companion) in the immersive space, and not just any moving object. Without participants knowledge, in the companion visual presence: none condition, the office fan motion was matched to the companion visually present group's motion (camera, character) motion. The main difference between the non-social presence of a fan and the social presence of the non-humanoid and humanoid companion conditions, was that the fan did not signal any companion social disposition towards the participant, therefore was socially meaningless.

Similarly, to the companion visually present conditions, in the companion visually absent (CVP: none) condition, the participants were also made to believe that their performance is evaluated by either an AI algorithm or a human minded companion, however, there was no visual representation of an interactive companion in the scene.

4.2.6 Stimuli

Similarly, to the experiments in the earlier chapters, the current study used a Relational Reasoning Paradigm (RRP). Both easy and difficult conditions were presented for a fixed duration of 3.5 seconds, following 0.5 seconds of a blank screen, so participants had a total of 4 seconds to give an answer, until the transition to the next trial. If the answer was not given during the 4-second interval, the answer was considered incorrect. Each monitoring block (monitored, not monitored) consisted of two difficult and two easy sub-blocks, five trials per each sub-block, in total there were 20 trials per one monitoring condition, beginning with either difficult or easy sub-block, followed by a complementing condition sub-block. Block sequences were counterbalanced between the groups and conditions. In total there were eight monitoring blocks, four monitored and four not monitored counterbalanced. Every new monitoring block was preceded with a 10-second on-screen message on the IVE TV screen: “You are now being watched” or “You are now not being watched”. The time of the message gave participants the time to look around and notice whether the companion was monitoring them or not (visually noticeable in the visually present companion groups). When the monitoring began, the virtual companion turned towards the participant and then at the screen, in no monitoring conditions the interactive virtual objects turned downwards, not facing the environment.

4.2.7 Procedure

Each participant was visually introduced to the RRP task outside of IVE and helped with adjusting the head-mounted display (HMD) as they were introduced to the 3D environment within IVE. During the introduction phase, the participants were asked to perform a practice task, with a 70 per cent passing threshold, both for Easy and Difficult trials. After the practice session completion, all participants were approached by the researcher, who made sure the participants are comfortable wearing the HMD and do not experience any simulation sickness.

The participants were assured that the researcher will be nearby in case of emergency, but unless the researcher will need to virtually monitor the participant's performance, they will be occupied otherwise. The participants were asked to inform the researcher when the immersive they complete the experiment, reinstating that otherwise, the researcher is not able to see their performance. After the study completion, the researcher helped with removing the headset. The participants then filled in a form on whether they believed in monitoring by their assigned companion agency, and if so, whether they felt judged. The researcher made sure participants understand the questionnaire, guiding them through it when needed. Participants were fully debriefed after the study and made aware of the social scripting used for the experiment.

4.2.8 Apparatus

The virtual environment was developed in an open-source 3D platform Blender and imported into the Unity game engine. The RRP stimuli presentation created in and generated through the Unity platform. The RRP image textures (originally used in Dumontheil et al., 2016) were edited to 20 % larger texture grain in Adobe Photoshop to reduce the Moire pattern effect inside the IVE. The humanoid character was a rigged 3D model mesh created in free software MakeHuman (www.makehumancommunity.org) and later imported to Blender 3-D editor for extra texturing. Both non-humanoid (tripod camera) and humanoid (digital researcher) were imported to and animated in the Unity game engine.

All the companion objects (humanoid companion, non-humanoid camera, non-social fan) were animated in Unity game engine replicating the main objects movement identically both in time and motion. To do so, the x, y, z axis parameters of the humanoid companion's neck and head motion were replicated to the axis parameters motion of the camera on the tripod and the motion of the fan on its stand. Through this application, the companions' dynamic motion towards the participants and their performance screen, as well as motion for non-engaging with participant and their performance was identical, performed by different virtual object. When the monitoring condition was "not monitoring", all objects motion was identical by lowering its main component (humanoid head, non-humanoid camera on tripod, non-social fan head on its stand) down to face the floor 45 decrees. In case of humanoid companion, the 45 degrees was showing them looking into their virtual laptop, disengaging from participant. All dynamic behaviours of the companion objects were piloted alongside colleagues assuring all objects movement is not out of place or unrealistic.

The animation of companion's behaviours (including non-social companion: fan) were set to loop after each monitoring trial. Each looping animation lasted 80 seconds, which was the maximum time a monitoring/not monitoring condition would last, based on the 20 trials 4 seconds each assigned by the experimental design. There were two animated looping behaviours, the watching down behaviour for not monitoring blocks, and the observing behaviours in monitoring blocks. The transitions between the blocks were animated as follows. When a monitoring block ended and not monitoring block began, the companion object would turn to the participant and then turn down, when the onscreen instruction said the next block condition. When a not monitoring block ended, and the monitoring block began, the virtual companion lifted their main component (head, camera, fan head) up to 85-degree angle turning towards the participant. The animation was programmed in a smooth manner not to scare the participant or draw too much unwanted attention. The behaviours were overall animated to be smooth, natural as possible, and not purposefully distracting. Considering the participants had to focus on the task, not the object, the repetitive looping of animation seemed sufficient for animating social presence. The recurrence of looping behaviours was not picked up during piloting with peer researchers. When asked whether participants noticed any repetition, a very few participants said they did. The only participant that did report some repetition was the one who also suggested they did not pay attention to task, but rather watched the companion. They were removed from the analysis.

The experiment was conducted through a Unity game engine. Stimuli were presented on a virtual reality supporting laptop and projected through Oculus Rift DK developer headset (resolution: 960 x 1080 pixel per eye, Refresh rate 75 Hz, with a 100-degree field of view.

4.3 Results

Participant Group Distribution

After the participant's exclusion, there was an overall similar participants distribution within the between-subjects groups, see **Table 4.1**.

Table 4.1
Number of Participants Per Each between Subjects Group.

Companion Agency	Companion Visual Presence	Participants in Group
Human	Absent	18
	Present Non-Humanoid	18
	Present Humanoid	17
	Total	**53**
AI	Absent	17
	Present Non-Humanoid	17
	Present Humanoid	16
	Total	**50**
	Grand Total	**103**

The data normality checks were conducted within each of the difficulty levels, for accuracy and RT separately. The test revealed that for accuracy, but not RT, the overall data distribution was significantly skewed as measured by Kolmogorov-Smirnov, for difficult t (103) = .161, p < .001 and easy t (103) =.144, p < .001. Therefore, the results for accuracy will be reported corrected when the data does not satisfy homogeny or sphericity assumptions. The summary of means and standard errors (SE) for each factor and their corresponding levels in Experiments

Three is presented tables below, accuracy is presented in ***Table 4.2***, and retinotomies (RT) in ***Table 4.3***.

Table 4.2

The Means (M) And Standard Errors (SE) Of Percent Accuracy (%) All the Levels by Each Factor Within the Experiment Thee Design.

Companion Agency	**Companion Visual Presence**	**Monitoring**	**Difficulty**	***M***	***SE***
Human	None	Monitored	Easy	95.30	1.19
			Difficult	88.75	2.64
		Not Monitored	Easy	95.30	1.26
			Difficult	89.15	2.75
	Present Non-Humanoid	Monitored	Easy	94.59	1.19
			Difficult	91.17	2.64
		Not Monitored	Easy	95.73	1.26
			Difficult	93.88	2.75
	Present Humanoid	Monitored	Easy	93.82	1.22
			Difficult	81.90	2.71
		Not Monitored	Easy	95.78	1.30
			Difficult	84.77	2.83
AI	None	Monitored	Easy	95.17	1.22
			Difficult	85.52	2.71
		Not Monitored	Easy	94.57	1.30
			Difficult	87.78	2.83
	Present Non-Humanoid	Monitored	Easy	95.03	1.22
			Difficult	88.69	2.71
		Not Monitored	Easy	94.72	1.30
			Difficult	90.05	2.83
	Present Humanoid	Monitored	Easy	88.91	1.26
			Difficult	81.09	2.80
		Not Monitored	Easy	91.35	1.34
			Difficult	77.91	2.92

Table 4.3

The Means (M) And Standard Errors (SE) Of Reaction Times (RT) For All the Levels By Each Factor Within The Experiment Three Design.

Companions Agency	Companion Visual Presence	Monitoring	Difficulty	*M*	*SE*
Human	None	Monitored	Easy	1574.08	64.26
			Difficult	2077.51	70.04
		Not Monitored	Easy	1496.83	63.14
			Difficult	2017.70	72.33
	Present Non-Humanoid	Monitored	Easy	1590.04	64.26
			Difficult	2011.51	70.04
		Not Monitored	Easy	1562.18	63.14
			Difficult	1943.01	72.33
	Present Humanoid	Monitored	Easy	1762.29	66.12
			Difficult	2237.10	72.07
		Not Monitored	Easy	1702.37	64.97
			Difficult	2204.80	74.43
AI	None	Monitored	Easy	1697.76	66.12
			Difficult	2156.81	72.07
		Not Monitored	Easy	1678.91	64.97
			Difficult	2138.99	74.43
	Present Non-Humanoid	Monitored	Easy	1639.89	66.12
			Difficult	1940.44	72.07
		Not Monitored	Easy	1548.28	64.97
			Difficult	1900.82	74.43
	Present Humanoid	Monitored	Easy	1726.71	68.15
			Difficult	2077.25	74.29
		Not Monitored	Easy	1731.60	66.97
			Difficult	2052.64	76.72

4.3.1 Difficulty

For accuracy there was a significant main effect of difficulty, F (1, 97) = 65.06, $p < .001$, $\eta p^2 = .40$, power > 99%, with difficult trials (M = 86.87, SD = 11.30) performed significantly worse than easy (M = 94.24, SD = 4.78) trials. For RT, there was also a significant main effect of difficulty, F (1, 97) = 329.99, $p < .001$, $\eta p^2 = .77$, power > 99%, with difficult trials (M = 2061.87, SD = 303.40) performed significantly worse than easy (M = 1640.22, SD = 266.24) trials.

4.3.2 H1: Mere Presence Effect (MPE)

As per the SFE prediction, there was a companion visual presence (CVP) x difficulty interaction, significant in accuracy F (2, 97) = 4.69, p = .011, ηp^2 = .09 (Greenhouse-Geisser, power 77 %), and marginal in RT, F (2, 97) = 2.39, p = .097, ηp^2 = .047 (Greenhouse-Geisser). The planned simple effects analysis investigated the interaction by the two levels of difficulty separately.

H1.a: Companion Presence vs Absence

The hypothesis ***H1.a*** predicted that any companion visual presence (CVP: present) versus when companion is absent (CVP: none) will elicit MPE.

Accuracy. As per planned pairwise comparison, the interaction was broken down by difficulty, contrasting the impact of visually absent companion (CVP: none) versus visually present companion condition (CVP: present; the combination of present non-humanoid and humanoid companion), at easy and difficult trials separately. The results showed no significant difference in the planned presence contrast within the difficult, t (100) = 0.72, p = .47 (absent M = 87.83, SD = 9.56, versus present, M = 86.37, SD = 12.13), or easy condition, t (100) = 1.35, p = .18 (absent M = 95.09, SD = 3.7, versus present, M = 93.81, SD = 5.1).

Reaction Times. The marginal CVP x difficulty interaction was broken down the by difficulty, contrasting the impact of visually absent companion versus visually present companion condition (the combination of present non-humanoid and humanoid companion), at easy and difficult trials separately. The results showed no significant difference in the planned presence contrast within the difficult, t (100) = 0.81, p = .42 (absent M = 2096.45, SD = 230.78, versus present, M = 2044.04, SD =

334.89), or easy condition, *t* (100) = *.90 p* = .37 (absent *M* = 1609.40, *SD* = 238.30, versus present, *M* = 1656.10, *SD* = 279.90).

Summary. There was no significant SFE related interaction, nor facilitation observed, in accuracy or RT, due to mere presence of any type of companion (CVP: present) versus when companion was not present (CVP: none). There is no supportive evidence for ***H1.a*.**

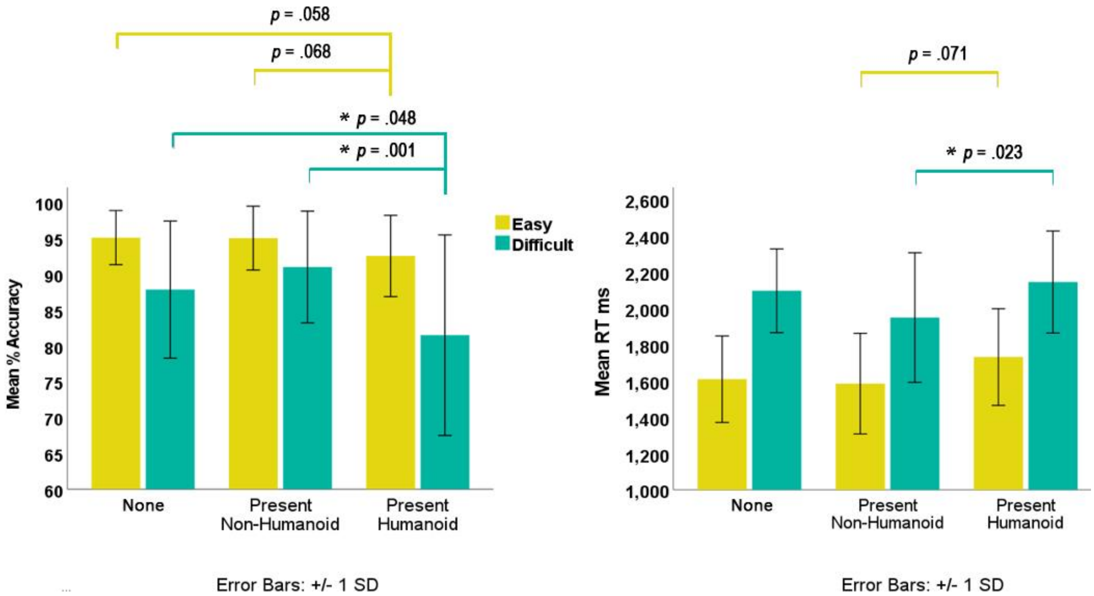
H1.b: Presence of Companion Type

The hypothesis ***H1.b*** predicted that humanoids companion visual presence (CVP: humanoid) will be most impactful in contrast to CVP: none humanoid and CVP: none. With linear impact on the easy and difficult condition SFE trajectory and the companion presence becomes more influential (from none to non-humanoid to humanoid).

Accuracy. The planned (Bonferroni corrected) pairwise comparisons tested the interaction at each level of CVP, broken down by levels of difficulty. For difficult conditions the present humanoid companion group (*M* = 81.48, *SD* = 13.99) performed significantly, *p* = .001, worse than present non-humanoid (*M* = 90.99, *SD* = 7.79) and visually absent (CVP: none) companion group (*M* = 87.83, *SD* = 5.60), *p* = .048. The present non-humanoid and visually absent (CVP: none) groups being not statistically different from one another, *p* = .67. Similarly, for the easy conditions, the present humanoid (*M* = 92.53, *SD* = 5.67) group performed marginally worse than the present non-humanoid (*M* = 95.02, SD = 4.45), *p* = .068, and visually absent (CVP: none) companion group (*M* = 95.09, *SD* = 3.78), *p* = .058. The present non-humanoid and visually absent (CVP: none) companion group performances being not statistically different ($p > .99$). There was no SFE facilitation of easy tasks, see **Figure 4.6, a.** below for the descriptive mean relationships.

Figure 4.6

The figure illustrates findings from the MPE: Presence of Companion Type, in Accuracy and RT between each of the CVP levels, per each difficulty condition separately.



a. Accuracy **b.** Reaction Times

Note. Means and one standard deviation (1 SD) of MP related accuracy and RT of performance, **a.** The visual presence of a humanoid companion is reducing participant's performance in accuracy, significantly in difficult and marginally on easy conditions**. b.** the visual presence of a humanoid companion marginally slows down correct responses both in easy and difficult tasks in contrast to present non-humanoid companion.

Reaction Times. The Bonferroni corrected pairwise comparisons explored the interaction at each level of CVP, broken down by levels of difficulty. For difficult conditions the present humanoid companion group ($M = 2144.83$, $SD = 280.94$)

performed significantly worse, p = .023, than present non-humanoid (M = 1949.02, SD = 357.17) and numerically worse than visually absent (CVP: none) companion group (M = 2096.54, SD = 230.79), p > .99. The present non-humanoid and visually absent (CVP: none) groups being not statistically different from one another, p = .11. For the easy conditions, the present humanoid (M = 1731.48, SD = 116.32) group performed marginally worse than present non-humanoid (M = 1584.98, SD = 277.33), p = .071, and numerically worse that visually absent (CVP: none) companion group (M = 1609.39, SD = 238.30), p = .19. With no significant differences between visually absent and present non-humanoid companion,

p > .99**,** see **Figure 4.6, b,** below.

Summary. There results indicated that both RT and accuracy were negatively affected by the presence of humanoid companion (CVP: humanoid), both on easy and difficult tasks. There was not SFE related interaction. There was no significant difference between the non-humanoid (CVP: non-humanoid) and no visual companion presence (CVP: none). The impact of humanoid presence did elicit a social response, in contrast to other types of presence, as per ***H2.b*.**, however the effect is detrimental, without facilitation, which is not in line with SFE.

4.3.3 H2: Audience Effect (AE)

The interaction of companion agency x monitoring x difficulty was non-significant $F\ (1, 97) = 0.28,\ p = .87,\ \eta p^2 < .001$ for accuracy, and RT F (1, 97) = .526, p = .470, ηp^2 = 0.005. However, as breaking down the effects of monitoring within each level of companion agency and difficulty was planned under ***H2.b*** this non-significant interaction was explored further. But due to the non-significant interaction all comparisons were Bonferroni corrected.

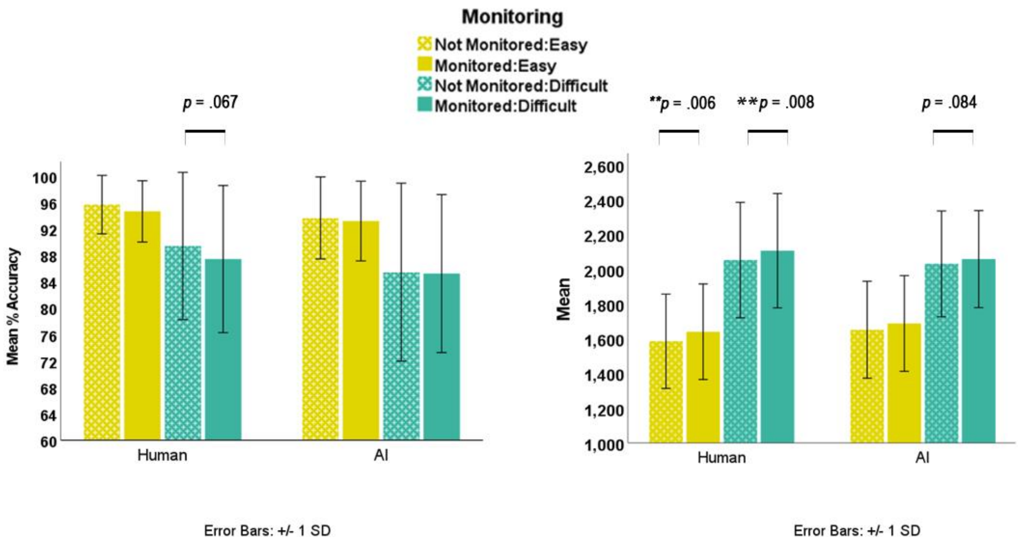
H2.a: AE Irrespective of CVP

Accuracy. The follow-up analysis for the main effect of monitoring explored whether the performance changes within each of the companion's agency (Human or AI) groups were affected differently. The results showed that although the monitoring decreased participants performance accuracy numerically, both in the AI agency group (not monitored M = 89.49, SD = 9.09, versus monitored M = 89.15, SD = 8.11), and Human companion groups (when not monitored M = 92.47, SD = 6.21, versus when monitored M = 90.98, SD = 6.39), the effect was only significant when participants believed that monitoring occurred by another person (Human groups p = .021, ηp^2 = .054) and not AI (p = .62 , ηp^2 = .003). The planned analysis of monitoring x difficulty interaction at each companion level revealed that monitoring by a human companion marginally decreased the accuracy of the performance on the difficult (p = .067, ηp^2 = .034) with no significant changes on easy trials (p = .139, ηp^2 = .005), see **Figure 4.7, a**. When breaking down effects by difficulty, there were no significant for AI companion when monitored versus not, easy p = .478, ηp^2 = .022, difficult p = .894, ηp^2 < .001.

Based on the results from the breakdown contrast per each companion at the level of monitoring and the monitoring x difficult interaction, it seems that monitoring by human companion significantly decreased performance overall, but only marginally on difficult tasks when broken down by difficulty. The finding only partially supports ***H2.a***, considering that the monitoring indeed affected the human companion agency groups only, however, the results did not support the prediction that monitoring will result in the SFE based interaction.

Figure 4.7

Mean And 1 Standard Deviation (1 SD) of AE related Accuracy and RT of Performance.



a. Accuracy **b.** Reaction Times

Note. The planned comparisons within companion agency demonstrate that for accuracy **a.** For accuracy, monitoring decreased participants' performance marginally only in the human companion group, and only on the difficult task. For RT, **b.** the monitoring decreased performance both in AI and human companion

Reaction Times. For RT, the results showed that both companion agency groups performed slower when monitored (Human *M* = 1873,08, *SD* = 274.27; AI *M* = 1872.57, *SD* = 247.53), versus not monitored (Human *M* = 1818.64, *SD* = 279.70, AI *M* = 1840.86, *SD* = 256.66), however human groups condition effect was larger $p < .001$, $\eta p^2 = .125$, than AI group $p = .040$, $\eta p^2 = .043$. The planned follow up three-way analysis investigating whether difficulty was affected differently during monitoring by an AI or Human companion, revealing that for AI companion there was a marginal performance decrease for easy (marginal, p = .084, ηp^2 = .030) and none for difficult (p = .181, ηp^2 = .018) trials. The monitoring by human-minded companion however has significantly affected both the difficulty levels, with monitored tasks performing significantly slower both for easy, p = .006, ηp^2 = .075, and difficult trials, p = .008, ηp^2 = .071.

Based on the results from the breakdown contrast per each companion agency level of the monitoring x difficult interaction, it seems that monitoring decreased performance overall both for human (significant) and AI (marginally) companions (**Figure 4.7, b**), when broken down by difficulty. The results support the ***H2.a***, that performance is significantly affected by a human-minded companion, however SFE related facilitation did not occur, only performance detriment. groups, yet the significant difference was only in the human companion group.

Summary. As per hypothesis ***H2.a.,*** the human-minded (companion agency: human) companion monitoring impacted participants performance significantly and close to significant. There was only marginal effect for AI companion. The monitoring however did not result in AE related social facilitation, only decreasing participants performance. This goes against the predicted effect of social facilitation.

H2.b: AE accounting for CVP

The interaction of companion agency x monitoring x CVP x difficulty was non-significant for accuracy *F* (2, 97) = 2.14, *p* = .12, ηp^2 = 0.042, nor for RT *F* (2, 97) = 1.20, *p* = .25, ηp^2 = 0.028. The Bonferroni corrected contrasts revealed that for human-minded companion, the monitoring by the humanoid CVP decreased performance on difficult task in contrast to non-humanoid companion, significantly for accuracy, humanoid (*M =* 81.90, *SE* = 4.95) versus non-humanoid (*M =* 91.20, *SD* =), *p* = .048, ηp^2 = 0.064, and marginally for RT, humanoid CVP (*M =* 2237.10, *SE* = 356.73) versus non-humanoid (*M =* 2011.50, *SE* = 346.68), *p* = .081, ηp^2 = 0.050.

Summary. There was no significant facilitation of CVP presence on the easy task performance during monitoring and no expected linear performance impact with an increase in social influence relating, the ***H2.b*** was not supported.

4.3.4 Companion Visual Presence (CVP)

There was a significant main effect of companion visual presence in accuracy (CVP), *F* (2, 97) = 7.22, *p* = .001, ηp^2 = .13, and RT, *F* (1, 97) = 3.88, *p* = .024, ηp^2 = .074. The effects were explored in post-hoc independently from the SFE effect. The Bonferroni corrected pairwise contrasts tested the effects of CVP social influence impact as per TMSI, at three levels of presence.

CVP Type impact

Accuracy. Contrast revealed that a present humanoid companion (*M* = 87.00, *SD* = 8.55) led to significantly worse performance than both the visually present non-humanoid companion (*M* = 93.0, *SD* = 5.61), *p* = .001, and visually absent companion (*M* = 91.46, *SD = 6.02*), *p* = .024, the visually absent companion performing numerically, but not significantly worse than present non-humanoid companion groups, $p > .99$.

Reaction Times. The performance was slowest in the present humanoid companion group (M = 1922. 19, SD = 242.45), being significantly different to the present non-humanoid companion group (M = 1762.20, SD = 288.27), p = .019, however just numerically, but not statistically, different from the visually absent companion group (M = 1842.59, SD = 204.10, p = .55). The present non-humanoid companion group performing numerically fastest overall, however not statistically different from the runner-up visually absent companion condition (p = .44).

Overall, both for accuracy and RT, the results support the findings in the *MPE: Presence of Companion Type* above, suggesting that there was an overall effect of the distraction of the present humanoid companion, with no facilitation at any task difficulty levels. The same effect persisted in *AE: AE accounting for CVP* above, with monitored human-minded companion participants performing worst when the companion was present humanoid.

4.3.5 Monitoring

There was also significant main effect of monitoring both in accuracy F (1, 97) = 3.95, p = .050, ηp^2 = .039 and RT F (1, 97) = 16.66, p < .001, ηp^2 = .147. The post-hoc analyses revealed that for accuracy, not monitored conditions (M = 91.03, SD = 7.85) performed overall more accurately than the monitored conditions (M = 90.09, SD = 7.29). For RT the monitored (M = 1872.83, SD = 267.67) conditions performed slower (worse) than non-monitored conditions (M = 1829.43, SD = 267.67). Overall monitoring was significantly detrimental to performance.

4.3.6 H3: Social Context Effect

H3.a: Impact of Companions' Mind

The **H3.a**, relating to overall social context effects, predicted that due to overall anticipation anxiety of performing under the human-minded companion, the performance will be worst in human companion agency groups versus AI agency groups.

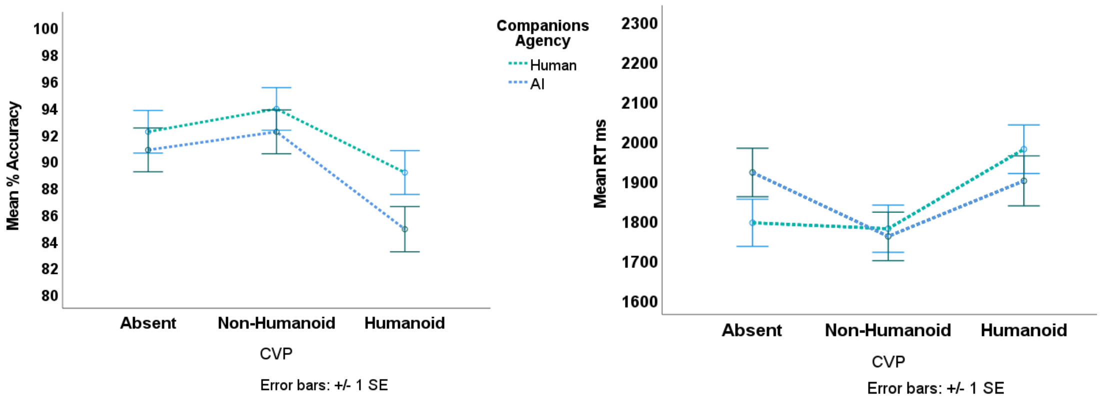
For accuracy there was a marginal main effect of companion agency F (1, 97) = 3.34, p = .07, ηp^2 = .033, with Human companion groups (M = 91.73, SD = 6.92) performing overall marginally more accurate than the AI companion group (M = 89.32, SD = 8.23). For RT, there was no main effect of companion agency, F (1,97) = 0.35, p = .85, ηp^2 < .001. Although there was a significant interaction of difficulty x companions Agency F (2, 97) = 4.06, p = .047, ηp^2 = .040, the human versus AI contrasts did not reach significance when contrasted at each difficulty levels separately. The results do not support the prediction that performing under human versus AI context in IVE might be detrimental to performance, as found in experiment one.

H3.b: Impact of Perceived social Influence

For the planned exploratory additive context effect of CVP and companion agency, the hypothesis **H3.b** predicted that the performance impact will increase linearly as the companion perceived social influence increases. The highest level of impact is expected in companion agencies: human minded groups and the CVP present humanoid condition, and the lowest impact in AI companion groups and absent (CVP none) companion condition. The effects were explored as a contrast of human versus AI companion groups per each CVP level, predicting worst performance in higher social influence groups (**Figure 4.8, a** and **Figure 4.8, b**).

Figure 4.8

Interaction Plot Showing the Trend of Means and Standard Errors (SE) of Overall Performance Impact Relating to Perceived Social Influence as per Hypothesis H3.b.



a. Accuracy **b.** Reaction Times

Note. The interaction plots demonstrate the relationship between the companion agency and companion visual presence (CVP), as part of the analysis for the general social context effect estimates based on the social influence levels, as per the threshold model of social influence (TMSI).

Accuracy. For accuracy, the trend (see **Figure 4.8, a** below), indicates that the human-minded companion groups performed overall better than AI companion groups, as demonstrated in Social Context Effects: *Impact of Companions Mind* above, with a significant performance drop in humanoid CVP groups for both AI and human-minded companion.

The follow-up contrast, testing how companion agency groups differed based on their CVP overall, revealed that when breaking down the effects by CVP, the human-minded companion group performance was marginally better than AI group performance under the humanoid companion presence, p = .078, ηp^2 = .032. There were no other statistically significant findings in contrast to accuracy.

Reaction Times. For RT, based on the interaction graph (**Figure 4.8, b**), the human-minded companion group seemed to perform significantly better than AI when there was no visually present companion (CVP: none), and worse when the humanoid companion was present. However, the statistical analysis revealed no significant nor marginal differences between the companion agency groups at these levels of CVP, during CVP: none, p = .14, ηp^2 = .22, and during present CVP: humanoid conditions, p = .37, ηp^2 = .008.

Summary. Overall, the findings for social context effect suggest that the type of companion visual presence and the type of companion agency do contribute to performance changes irrespective of monitoring or task difficulty. However, the participants performed overall better under human companion that AI, not supporting the **H3.a.** hypothesis that evaluation anxiety under human-mind companion might overall decreases performance in immersive space. The presence of humanoid companion was, however, most detrimental to the participants performance, however it did not reliably linearly decreased participants performance significantly when interacting with most impactful human-minded companion condition. Therefore, the **H3.b** was not supported.

4.4 Discussion

The current study investigated the social facilitation effect (SFE), within the immersive virtual environment, focusing on parsing the audience effect (AE) and mere present effect (MPE). Similarly, to the online video conference experiments in this thesis, this study measured the participant's cognitive performance (on the relational reasoning paradigm: RRP) changes under the mere co-presence with the companion (MPE-m) and when the companion is monitoring the participant's performance (AE-m). There were several factors in this study. Firstly, the companion visual presence (CVP), which was measured in the current study at three levels. The co-immersion with companion in this study was either under no companion visual presence (CVP: none), when companion was present but not humanoid (CVP: non-humanoid), and when companion was present and humanoid (CVP: humanoid). The second variable was companion agency (who drives the companion), at two levels, AI or human. The final social context variable was, as with previous studies, the attentive monitoring of participants performing by companion, at two levels, monitored and not monitored. The participants performance, as with previous experiments was measured at two difficult levels, easy and difficult. There were several MPE and AE related hypotheses postulated based on the relations of companion's agency and companion visual presence types.

Firstly, the MPE hypothesis ***H1.a*** predicted that any companion presence (CVP: non-humanoid, and CVP: humanoid combined) in an immersive environment will elicit MPE in contrast to when companion is not visually co-present with participant (CVP: none). This hypothesis was not supported by the data. However, the hypothesis ***H1.b***, that the companion humanoid immersive presence will be most impactful, was indeed supported by the results. Tasks performed under humanoid companion demonstrated a significantly worse outcome than in other CPV types, with no significant differences between non-humanoid and no companion (CVP: none) visual presence conditions. Although, the effect of humanoid versus other CVP groups were significant for accuracy and reaction times (RT), the results showed an overall task detriment and not facilitation, not supporting SFE. Additionally, there was no linear SFE impact as the companion CVP increased. Therefore, the hypothesis ***H1.b*** was not fully supported. The humanoid presence was possibly socially distracting to the participants with no evidence of social positive arousal. This conclusion is supported by a significant overall main effect of CVP for accuracy and RT, irrespective of difficulty, suggesting that the humanoid companion group performed significantly worst overall irrespective of difficulty. Interestingly, the humanoid companion difference was significantly consistent in relation to the present non-humanoid companion, but not always so to the visually absent (CVP: none) companion.

For the AE, there were also two hypotheses, with the planned comparison of the companion agency × monitoring × difficulty interaction. The ***H2.a***, for AE, predicted that monitoring will only impact human-driven companion groups, but not the groups with AI-monitoring companion. The analysis tested the monitoring impact per human-minded and AI-minded companion agency separately, at each difficulty level. The results showed that indeed the performance was significantly affected overall only during monitoring by another person (human-mind), however the effect was detrimental, with no facilitation for accuracy marginal in difficult task, and significantly detrimental both in easy and difficult tasks. There was also an overall significant effect of monitoring, demonstrating that being monitored in IVE, irrespective of companion agency, was significantly detrimental to participants' overall in accuracy and RT. The results overall support the AE hypothesis ***H2.a***, that monitoring by humans, but not AI, companion impacts participants' performance. However, there was no SFE facilitation.

Additionally, to the ***H2.a***, the analysis investigated the contribution of increasing CVP to the AE. Therefore, the ***H2.b*** predicted that based on the threshold model of social influence (Blascovich, 2002), the companion visual presence might amplify the effect of monitoring, suggesting a linear positive relationship of performance impact as the CVP increases. When testing CVP differences during monitoring (in the human-minded companion group only), again the humanoid companion group performed significantly less accurate and marginally slower, however, there was no linear relationship of the increasing impact of CVP based on the social influence model, therefore not supporting the hypothesis (***H2.b***) relating to CVP influence related contribution to AE.

Lastly, the study investigated the social context effects of overall performance under the human versus AI-driven companion independent and in consideration of increasing levels of CVP. The impact was expected based on the possible detrimental effects of performance under evaluation anticipation anxiety. Predicting that, as with experiment one, the participants might perform worst overall under a human minded companion (***H3.a***) and more so under a socially influential humanoid presence of higher CVP (humanoid) and companion agency (human) (***H3.b***). The analysis revealed that participants performed marginally more accurately under a human companion, with no significant difference in performance speed (not supporting ***H3.a***). This effect was in the opposite direction to the videoconference performance, which was overall worse in the context of a human companion than AI companions. There was no significant interaction between the CVP and companion agency impact. Overall, the higher level of companion CVP did decrease the performance (RT and accuracy), however, the human-minded companion overall effect marginally facilitated the accuracy but not the speed of performance (not supporting ***H3.b***). Similarly, to the findings from the MPE, the results show that humanoid companion's immersive presence is debilitating to the performance.

In summary, the current immersive experiment findings were overall inhibitory and mostly not reliant on the differences between task difficulty, which suggests that they were possibly not SFE related. In ***General Discussion*** I examine how task difficulty and the type of task used can influence the SFE outcomes. Considering there seemed to be a positive skew and ceiling effects in the performance accuracy throughout the three experiments in this thesis, it is possible that the RRP difficult task might not have been difficult enough and the easy task was too easy to show significant improvement. Although task difficulty might not have been sufficiently adjusted for SFE in the current series of studies, the fact that the performance trajectory changed, in the current immersive experiment versus video experiment, is thought provoking. The current results show that socially motivated performance change, which was inhibitory, is the opposite of the findings in the video-based experiments reported in this thesis, which were facilitatory. Additionally, the social context effect of AI versus the human minded companion was also the opposite to the findings in the video-based experiment. Although current findings do not support the directions of the previous two studies, these results are interesting in their own account.

There are several possible explanations for the changes in the directions of the effects. Firstly, the immersive environment is considered to be overall more cognitively taxing in contrast to the habitual video conference-based interaction in the real world (Makransky et al., 2019). If this is indeed the case, the higher overall cognitive load imposed by the IVE could have increased the overall difficulty level of tasks. And as the main effect of SFE suggests, in the social context more difficult task performance drops rather than gets facilitated, in contrast to when performing alone. Therefore, it is possible that adding the additional environmental processing load changes to the difficult task has led to its decline. However, when looking into overall mean accuracy of performance throughout the three experiments, the performance on both the easy and difficult tasks was best in the immersive environment. Taking into account the previously mentioned evaluation anticipation effect, it is possible that performance was highest in immersive reality because the participants were less worried about the evaluation in that space. However, that does not explain why there was no facilitation, at least in the difficult task,

Alternatively, there was no facilitation found in an immersive space because there was no sufficient main driving factor for facilitation. As discussed in the introduction of this chapter, and as demonstrated in experiment two, the self-visual presence (SVP) of the participant might be a crucial factor which leads to performance facilitation in SFE. The introduction of this chapter described how the SVP in the current immersive paradigm was limited to mere functional participants self-presence, mainly due to the hardware constraints of the virtual head-mounted display. Given the head-mounted display occlusion of the participant's face, we have attempted to elicit higher sense SVP by informing the participants that the companion can see where the participant is looking and how well are they performing, what was called the functional SVP in the introduction. This approach was taken as there is in-real-world evidence that participants feel observed and adjust their social behaviours, merely during eye-tracking and neurofunctional scans, irrespective of whether they themselves can be seen (Wong & Stephen, 2019). However, it is possible that this level of self-processing is not sufficient to generate self-referential processing in IVE. Indeed, research on self-presence in immersive virtual reality platforms (Seo et al., 2017) suggests that being recognised and identified through self-presence is what drives the pro-social behaviours in the immersive space. If reputation management, and self-reflection driven though self-imposed, is indeed a significant part of the SFE equation, as was the case in video experiment two, and it is reliant on higher levels of identifiable SVP, then SVP in the current paradigm was possibly not sufficient to elicit facilitation. This interpretation would also explain why the companion agency impact was the opposite in this immersive study in contrast to video conference-based interaction, considering that evaluation anxiety might not occur if the participant does not feel judged and self-conscious. Without the SVP facilitation, it is possible that the humanoid companion presence was just more socially distracting than the other CVP presence types, as per first person but not second person cognition perspective. However, whether this effect is due to higher immersion or merely the humanoid form of the companion is yet to be established. Further rigorous testing is required to test these assumptions, both within and between the immersive reality and video conference-based interaction, as well as further into the mixed reality paradigms that enable testing with realistic-self exposure within the environment.

As social media companies and technology developers are still deciding what the augmented social interaction future will look like, there are new opportunities that enable testing of levels of self-and companion presence. Some of these methods are the virtual caves and augmented reality, both of which bring the virtual world into people's own realistic environments, merging the digital and real world in a way prior unexperienced. One of the main benefits of such reality merger is that the self-presence of the protagonist is always realistic, as they are experiencing the mixed reality as their own realistic self, whilst interacting with the projections of others. In the final chapter of this thesis, I will propose ways forwards on further testing in new platforms, and how these new layers of self and others presence might be perceived differently than virtual and video communication.

Although the current experiments findings are interesting, more questions arise through these immersive results and their generalisation to the in-real-world social scenarios. The immersive environments are no doubt robust platforms for testing cognitive impacts of social interaction with others. Paraphrasing (Blascovich et al., 2002), the immersive virtual reality is a unique tool that helps us to pick apart and reverse engineer the most complex behaviours in controlled systematic, yet ecologically valid, way. However, it is important to note that, as with every technological tool, there are limitations that need to be considered, and immersive virtual interaction is currently far from replicating in-real-world communication with high validity. Irrespectively, the immersive reality seems to be the right tool to explore emerging trends of social interaction, especially if the interest in social immersive experiences increases and the technologies improve to levels of what was considered science-fiction just a few decades ago. As the technologies progress, so should our understanding of what impact they might have on our lives, and whether these impacts are worth the investment. In the final chapter, I will summarise the findings from the three-experiment conducted and discuss the possible ways forwards for the application of video and immersive virtual platforms, both in the research and industry and wellbeing sectors. I will then suggest the ways forward in researching social perception in the new augmented social reality realms.

Chapter 5: General Discussion

Summary of Findings and Conclusions

Summary of Findings and Conclusions

As people develop, learn, and perform daily tasks, they share their functional environment with other people. Virtual interaction technology is rapidly reshaping the understanding of what mutually shared functional environments are, and what meaningful social interaction with another person is. As humanity progresses into this new area of augmented social interaction, it is paramount to learn more about people's perception of this extended reality and others within it. Learning about the social brain in these new technology-driven realms can help us develop more wellbeing-oriented interaction platforms, but also teach us more about human cognition in ways that real-world communication could not.

This thesis was motivated by the currently prominent idea of social processing – the second person cognition, which suggests that the brain perceives social interaction differently when the person is socially involved in the interaction, rather than when the person is merely observing it (Schilbach et al., 2013). Through the prism of second-person cognition, the participant is no longer a passive social observer, they are an adaptive protagonist within a social context. Second-person cognition can be expressed both through verbal and non-verbal communication (Cañigueral et al., 2022). However, the research in real-world face-to-face interaction suggests that the baseline states of second-person cognition can be achieved just through participant's belief of another person's presence, either cognitive (monitoring) or physical (co-presence; see **Chapter One: Mere Presence and Audience Effect)**. Considering the significance of other people's physical co-presence in the real world (**Chapter One: Social Presence in Real-world)**, the thesis argued that it is important to investigate this effect in the virtual domain, especially considering that virtual interaction an important part of modern day to day communication. The focus of this thesis was to test whether the social impact, based on virtual companions' mere co-presence and monitoring, is experienced similarly in the virtual communication platforms, videoconference and immersive interaction, as it has been reported in the real world.

To assess whether the state of co-presence and monitoring can be elicited remotely through virtual platforms, the three experiments in the current thesis measured the corresponding cognitive impacts believed to be related to two baseline states of second person cognition in the real world (Hamilton & Lind, 2016): the mere presence effect (MPE; the state of co-presence) and the audience effect (AE; the sense of being watched). The three experiments in this thesis reveal the complexity behind these seemingly simple mechanisms of social cognition. Based on the results in the current thesis I propose the possible implementations of the current findings for the development of socially meaningful virtual platforms in the future. Hopefully, this work will start a conversation on the potential impacts of the upcoming virtually augmented social reality era and inspire more research in this growing field.

5.1 General Overview

The current thesis investigated participants' cognitive performance changes alongside a virtual companion within two different virtual social contexts, during a videoconference and an immersive virtual reality interaction. To test cognitive impacts, the social contexts were experimentally varied based on participants' beliefs about their virtual companion, such as whether the companion is human-minded or AI-driven, and companions' visual properties, such as companions' co-presence alongside the participant and whether the companion is humanoid or not. The participant's self-visual presence, such as whether the participant could be seen in the environment, alongside a virtual companion was considered throughout the experiments and directly tested in experiment two.

The thesis investigated the phenomenon of the social facilitation effect (SFE) in a videoconference and immersive virtual reality setting. The research questions were postulated around the two different social contexts motivated SFE changes which are considered effect on their own – the mere presence effect (MPE) and the audience effect (AE). The MPE and AE differ in social mechanisms which elicit the effects, the MPE-mechanisms (MPE-m) is co-presence with conspecific and AE-mechanism (AE-m) is attentive monitoring by another person. This thesis focuses on the canonical SFE performance outcomes, motivated by the social context versus performance alone, which are as follows: the performance on the easy or well-known tasks improves (facilitation), whilst the performance on difficult or unknown task deteriorates (inhibition) in social context versus alone. These canonical performance changes have reported in the real world for both in non-human animals (Rajecki, 2010) and humans (Bond & Titus, 1983).

It is however important to acknowledge that for human participants the reported SFE sometimes did not follow the canonical effect. The lack of canonical effects is attributed to either insufficient task difficulty manipulation or type of task performed (meta-analysis: Bond & Titus, 1983) or participants individual differences in responding to SFE (review paper: Uziel, 2007). Similar to some of the previous findings, the three experiments presented in the current thesis did not find the canonical effect, experiments resulting either in social facilitation or inhibition.

Considering the SFE findings can be sensitive to type of tasks performed, perceived task difficulty, and to individual differences, it is tempting to drop the canonical difficulty x social context interaction from the SFE prediction. However, I still argue that it is important to measure the SFE as a canonical interaction effect of both at easy and difficult levels, as well as note down whether the effects are of facilitation of inhibition. This is because the interaction shows not only how performance changes through social motivation or distraction, but how participants subjective reality interacts with the social context. The canonical SFE interaction in humans demonstrates how participants perceived reality about self-competence interacts with the social mentalising over conspecifics thoughts and actions towards self, influencing the performance outcomes. The direction of how performance is affected, either inhibited or facilitated, can inform researchers of the cognitive load or motivation experienced by the participant during a particular social event. The effects can be either driven by subjective biases about self-competence, motivational or leading to cognitive overload, or environmental driven, such as distraction or higher vigilance. The results of these processes, although sometimes leading counterintuitive outcomes such as worse performance when trying harder on a difficult task, highlighting the complexity of second person cognition. It is important to consider both the task difficulty and inhibition/facilitation interactions, especially when applying the SFE findings in the educational, work and wellbeing settings. For example, both the performance drops due to discomfort, and performance improvements due well managed challenge, amplified by a conspecific, are important markers to consider when motivating a student performance online. Instead of dropping the canonical interaction with task difficulties within the SFE, more precise and creative approaches need to be applied experimentally to further learn about the SFE outcomes. These approaches should include eye tracking and neurofunctional techniques additionally to physiological markers and behavioural outcomes. For example, as mentioned in a review on SFE by Guerin & Innes (1984), although there might be an innate need to monitor the companion, counterintuitively, the gaze behaviour towards the co-present companion is restricted alongside a more restrictive demeanour. Combining the eye tracking method with neuroimaging could find an interaction between processes of attention modulation and gaze contingencies in participant when companion is present versus none. This could be tested both at the level of second person cognition, when participant is part of the social environment and when they might just observe someone from first person perspective knowing they themselves are not visible or engaged with. The arousal measures could additionally demystify how attention, social processing and attention mediation change the state of distress or motivation, similar to Blascovich et al., (1999).

Over a century of SFE research shows that even if not all studies find the canonical SFE, the canonical SFE interaction in the real-world have been reported for decades (Guerin & Innes, 1984; Bond Titus, 1983). In contrast to real-world SFE, the findings within virtual realms are however scarcer, more inconclusive, and elusive in their effects (review article: Sterna et al., 2019). Most immersive studies testing cognitive performance SFE changes report only task inhibition (Emmerich & Masuch, 2016; Hoyt et al., 2003; Zanbaka et al., 2007). With other virtual studies report no SFE on cognitive performance outcomes, both during in-lab desktop virtual companion presence (Baldwin et al., 2016) or immersive companion presence (Hayes et al., 2010). Only two, same authors, reports on in-lab virtual desktop interaction demonstrated a canonical SFE, measured in reaction times (Park & Catrambone, 2007, 2021). Besides the inconclusive findings on the effect, the results are still divided on whether SFE can be elicited with human-minded avatar or AI agent companion, and whether the human-driven and AI-companion differ in their SFE impact.

The current thesis argued that the discrepancy within the current virtual SFE findings could be, at least partially, attributed to disregarding the discrepancies of underlying mechanisms that give rise to the effect, as virtual studies use the SFE as an overarching term, rather than state whether manipulation is of MPE and AE. These mechanisms could be particularly important in virtual SFE research contrasting the impact of human versus AI companions. Based on the threshold model of social influence (Blascovich, 2002b), the AI and a human-driven companion could differ in the exerted social influence within a particular social context, such as the co-presence (MPE) or observance (AE). The AE is believed to be driven by reputation management, reliant on the disposition of others towards the performing participant (Geen, 1991b; Hamilton & Lind, 2016d), and the MPE is believed to be reliant on more primitive mechanisms such as social distraction and uncertainty of others' actions within the co-inhibited mutual environment (Claypoole & Szalma, 2017, 2018; Guerin, 1986c; Sanders, 1981b). Therefore, the level at which the virtual companion can exert judgment or portray meaningful presence would depend on the companion's mind property (ability to mentalise from human perspective) and the significance of their interactive visual presence (see **Parsing Virtual Mind and Body Presence** respectively.

There were two main hypotheses set throughout the three studies, based on how the companions perceived mind property and the levels of companion's visual presence will affect participants' performance through either the MPE-m and AE-m. Firstly, if the sense of co-presence with a companion is sufficient within the virtual interaction platform, the visual presence of any interactive companion should elicit SFE through the mechanisms of MPE (MPE-m), irrespective of their agency (mind property) or attentiveness (monitoring) to the participant. The effect should arise if the companion's autonomous actions are of significance to the participant, and the companion's presence is sufficiently meaningful eliciting vigilance towards their potential behaviour. In this thesis, the impact of visual co-presence with a companion was tested at two virtual platform levels: in the videoconference-based setting (experiments one and two) and under a higher level of immersive co-presence in virtual reality (experiment three). In addition to testing the impact of the mere presence of a companion, the thesis tested the independent impact of AE-m – monitoring by companion. It was postulated that in the context, which is reliant on the companion's potential judgement over participants performance outcomes, there would be a significant difference in how a companion with a mentalising property (human-minded companion, such as an avatar) would impact the participant's performance in contrast to a companion without a mentalising property (AI-companion). Therefore, the second prediction was that through the mechanism of AE (AE-m), the SFE will be only elicited by the attentive monitoring of a human-minded companion (companion agency: human), but not AI-minded. These effects were tested at different variations of non-attentive co-presence and attentive monitoring throughout the three experiments.

Critically, this thesis argued that depending on the level of companion co-presence (attentive, non-attentive, or none) and their agency (the mind property of the companion: AI or human-driven), the interaction with a virtual companion can impact the participant's performance either through the MPE-m or the AE-m pathway, manifesting in SFE. Whether these routes are additive or independent was tested throughout the thesis.

The overall impact of performing under a context of a particular companion was explored throughout the series of studies, under the term the Social Context Effect. The social context effect was reliant on the notion that acknowledging the performance might be eventually evaluated by someone, sets an overall baseline of performance effort. Both practice and overall performance is performed under the umbrella of anticipating evaluation by a particular conspecific. The predictions for the baseline performance relating to social context were investigated as part of the idea of evaluation anticipation theory (Pulopulos et al., 2020; Starcke et al., 2008; see also Introduction *p* 32), relating to anticipation stress and anticipation anxiety. During evaluation anticipation, even if a person is not yet being evaluated, the participants overall state of alertness within a context might be elevated because the evaluation is expected eventually. The prospect of evaluation within a context of a higher social significance, by a real person in contrast to AI, raises the overall baseline level of alertness and preparedness within this social context. This higher state of anticipatory alertness could influence the general baseline of the performance outcome, prior to real-time monitoring or mere presence might even take place. The companion's overall impact on participant performance was predicted based on the concept of social significance (meaningfulness) within the threshold model of social influence by Blascovich (2002). Although because the direction of this effect was not clear, the analyses were mainly exploratory.

In addition to the companions' attributes, the level of participant's virtual self-presence was explored throughout the study, under the assumption that in the virtual interaction the self-exposure (self-visual presence) could be an important factor contributing to either the MPE or AE. The argument for the impact of self-presence was tested under the assumption that there cannot be co-presence (MPE) without sufficient self-presence, and the participant cannot be monitored if they are not seen. Experiment two tested the contribution of self-visual presence during videoconference both independently and in accumulation with companion's attentive and non-attentive presence. The performance impact of interest throughout the three experiments was the cognitive performance outcome on relational reasoning tasks, at easy and difficult levels. The impact was measured in RT and accuracy. The SFE impact was predicted to follow a particular performance change trajectory: improvement in performance on easy tasks and detriment in performance on difficult tasks, during a social context (presence or monitoring) versus when not in the context.

The next section summarises the experimental design, predictions and results for each experimental chapter **Experiments and Outcomes**, followed by the general conclusion and interpretation of the effects in the framework of MPE and AE, and the general social context effects. The summaries will be followed up by the **General Discussion**, **Limitations and Ways Forward**, and **Real-World Implementation** sections discussing how current findings map onto the virtual SFE literature, mentioning study limitations, industry impact and ways forwards.

5.2 Experiments and Outcomes

There were three experiments in the thesis, two experiments within a videoconference-based setting and one within an immersive virtual environment. Throughout the three studies, none of the experimental manipulations resulted in the predicted canonical SFE pattern of performance change, however, the results did demonstrate independent facilitative and inhibitory effects depending on whether the participant or companion was visually present, companion type, difficulty level, and the virtual platform utilised. The following subsections summarise the three experiments reported in this thesis, followed by the MPE and AE-related findings and the results from the exploratory analyses.

5.2.1 Experiment One

The focus of experiment one was to establish whether MPE and AE can be elicited in the videoconference-based setting and set a baseline for the following experiments. The participants performed the cognitive task during a live video call with either of the three levels of companion types: real human, avatar, or agent. All participants performed under three levels of social interaction: alone, during which both the participant media (video and shared screen) and companions media (video) were turned off; non-attentive co-presence, when the participant's video and screen-sharing were on and the companion was video present without attending to the participant; attentive co-presence, when participant's video and screen-sharing are on and the companion was video present whilst monitoring participants performance.

There were two main SFE predictions. Firstly, the MPE based SFE will occur under any co-presence condition, irrespective of social interaction and companion type. The results showed that participants' performance improved significantly on the difficult task both in accuracy and reaction times (RT) when the participant was video co-present alongside companions in contrast to when performing alone. There were no significant effects when the participants performed easy task, there was also no canonical SFE interaction. The second hypothesis stated that the AE based SFE will emerge only in the presence of an attentive (monitoring) companion who has a human mind (not the AI agent). The analysis contrasted the companion attentive presence versus non-attentive conditions per each companion type. The results showed that indeed only human-minded (real-human, avatar) companion attentive presence was impactful, however, there was no significant SFE-related impact. The attentive real-human video companion marginally improved the difficult task performance on the accuracy, the avatar attentive monitoring companion however marginally decreased the easy task accuracy whilst significantly speeding up the performance of the easy task. The AE were mostly marginal for human-minded companion groups, however there was no significant or marginal impact of monitoring within the AI agent group. The impacts of the attentive companion type were according to prediction, even if it lacked the canonical SFE. However, the avatar impact differed from the real-human video companion, which was unexpected and was investigated further in experiment two.

Overall, it was concluded that the co-presence (MPE) with a companion in the videoconference-based setting is facilitating and that only human-minded companions can elicit performance change during attentive monitoring (AE). However, from experiment one's results, it was still not clear why there was a different trend of impact when performance was under real human versus avatar companion. It was also not clear which levels of MPE, and AE are mainly driving the observed non-attentive co-presence-based facilitation and whether separating these levels further would lead to SFE-related impact.

5.2.2 Experiment Two

The purpose of experiment two was to investigate the underlying drivers of the AE and MPE during videoconference-based interaction building upon experiment one’s findings. Experiment two focused on parsing out the elements which could individually contribute to the social impact within virtual SFE – attempting to reverse engineer the effects. There were three main social interaction factors: companions’ visual presence (CVP) on video, participants' self-visual presence (SVP) shown to the companion in the video, and performance screen-sharing (PSS) of participants' task screen to the companion. All three factors were turned on and off, both in isolation and in combination, as per the on-screen command. The participants performed the same relational reasoning task as with experiment one, whilst their performance was either attentively monitored or not.

The companion type of experiment two was a virtual avatar. There were several reasons for choosing an avatar. The avatar is a hybrid companion, that has both the human mind property, a predicted requirement for AE, and a virtual body, a minimal predicted requirement for companion presence in MPE. Additionally, the avatar companion was most controversial in its impact in experiment one and required further investigation.

For MPE, it was predicted that the effect can be driven by either seeing the companion (CVP), being visually self-present (SVP) or a combined presence, co-presence, of being self-visually present alongside a visual companion. The factors were tested independently and in isolation. The results demonstrated that the MPE was only significantly impacted by the SVP of the participant. Turning the participant's self-visual presence on, irrespective of other variables (companion presence or screen-sharing), significantly improved the participant's performance. When the effects were investigated by each difficulty level separately (as per SFE), the SVP facilitated difficult task accuracy (replicating experiment one), and, when making sure the participants task sharing is not seen by the companion (performance screen-sharing, PSS: off) also on an easy task. The SVP when the task was not monitored (PSS: off) significantly facilitated performance speed both on an easy and difficult task. The companion presence did not contribute significantly to performance change, both as an independent factor and in combination with SVP. To summarise, as with experiment one, there was overall task facilitation which was attributed to the MPE, however, similarly, to experiment one there was no significant SFE idiosyncratic difficulty interaction effect.

The AE-based hypotheses tested how participants' performance monitoring by avatar companion contributed to the SFE-related arousal. The performance impact was tested when there was just mere monitoring of performance screen sharing, screen-sharing whilst being video seen, and when being seen and screen sharing with visually present versus absent companion. The performance screen sharing (PSS) improved easy task performance speed, replicating the avatar companion AE results in experiment one. Turning SVP on whilst having their performance monitored marginally improved difficult task accuracy, the result being best for the difficult conditions overall. There was no significant contribution of avatar companion visual presence during monitoring. There was no significant SFE-related impact on AE analyses, however the results replicated the significant effect of avatar condition AE in experiment one, the attentive monitoring significantly facilitated easy task performance speed.

5.2.3 Experiment Three

Experiment three tested whether the MPE and AE-related SFE arousal will be elicited under a more immersive interaction than videoconference, in which participants share the virtual environment with their companion. It was assumed that the lack of MPE-related SFE, especially the lack of companion visual presence impact, in the two videoconference-based experiments could be attributed to lacking the perceived sense of sharing a mutual environment with the companion, due to the MPE vigilance-related hypotheses (Green, 1984; Sanders, 1981). Therefore, the experiment three tested whether this level of MPE vigilance can be elicited within an immersive virtual environment, that was demonstrated to induce a higher perceived level of co-presence with virtual others in contrast to desktop interaction (Oh et al., 2018; Witmer & Singer, 1998) The participants performed the same cognitive relational reasoning task, performed in videoconference-based studies, within an immersive virtual setting with either a human-minded or AI-minded companion (companion agency). The companions accompanied participants at three companion visual presence levels (CVP): none, present non-humanoid (monitoring camera), and present humanoid. The companions were either monitoring participants performing the task by looking at both participant and the task, or merely present by looking away from the participant and the task. The participant's self-visual presence (SVP) within the immersive space was merely functional (due to virtual headset occlusion), the participant believed that the companion could monitor their gaze, head rotation and performance within the immersive space.

For the MPE, the first contrast looked into whether any visually present companion versus none would result in SFE. The second contrast tested whether humanoid companion presence would elicit SFE. The results demonstrated that any type of social companion presence is not sufficient for performance impact, however humanoid companion presence significantly decreased participants' performance both in accuracy and RT. The planned exploratory analyses suggest that impact was not difficulty related. Therefore, effects are mainly attributed to overall social distraction, not SFE. For AE, we tested the impact of companion agency (AI, human) and monitoring on participants' performance. As with experiment one, we predicted that monitoring will only elicit SFE in the human-minded companion group. Monitoring was significantly detrimental for the human-minded companion group in performance speed and marginally for accuracy.

However, the effects were not only in human-minded companion condition, but attentive monitoring also marginally reduced the performance speed for the AI companion group. The exploratory analyses of significant main effect monitoring revealed that monitoring overall significantly decreased performance accuracy and RT, irrespective of difficulty and companion agency. Due to the lack of SFE-related interaction during agency-based effects, it seems that the effect was related to the overall pressure of being monitored, rather than judgement by the human-minded companion. Overall, unlike the videoconference-based findings, the immersive findings were not facilitative, but only inhibitory. Additionally, although the monitoring in an immersive space seemed to impact participants' performance, the impact seemed to be more significant when measured irrespective of the companion's agency.

5.2.4 Results Interpretation and Discussion

The results from all three experiments suggest that virtual companion presence and monitoring can be impactful. However, the social impact seems to be dependent on several factors. The least intuitive factor, and least mentioned in virtual SFE literature, is the self-visual presence of the participant during the interaction. The following paragraphs summarise the impact, related to the MPE and AE, within the three experiments, focusing on how the properties of a virtual platform and testing conditions can influence the virtual MPE and AE outcome. Overall, the SFE-related findings in videoconference-based interaction were facilitative, whilst the same paradigm in an immersive environment was inhibitory. There was no canonical SFE-related easy task facilitation and difficult task inhibition observed. Although the findings might seem inconclusive at first, these differences observed within different platforms and testing environments could illuminate why virtual SFE are so elusive in literature.

The MPE results of the two videoconference-based experiments demonstrated that when the participants were realistically visually self-present in live video, their performance was overall facilitated both in RT and accuracy. Experiment one showed that the type of companion was not important for this facilitation to occur and experiment two highlighted the importance of self-visual presence for facilitation, whilst the companion visual presence did not have an impact. In contrast to videoconference-based findings, the MPE-related findings in an immersive virtual space (experiment three) had an overall inhibitory effect, without significant facilitation. Moreover, in an immersive virtual space, the humanoid companion's visual presence was overall inhibitory to the participant's performance (as measured in MPE). The inhibitory effect resembles the majority of immersive virtual SFE findings (Emmerich & Masuch, 2018; Zanbaka et al., 2007). It is worth highlighting that the same effect was not present for a non-humanoid companion presence, suggesting that the humanoid virtual companion form is important in an immersive setting. Therefore, it seems that the videoconference setting provides a sufficient level of self-exposure for performance facilitation, but not sufficient companion co-presence for potential social inhibition. Whilst the immersive environment provides a sufficient companion-based presence for inhibition, it does not provide enough self-visual presence for performance facilitation.

The reason why the current experiments have not reached the appropriate canonical SFE through the MPE-m could be that there was not sufficient balance between self-exposure and co-immersion with a companion within any particular testing platform used in the current experiments. Indeed, the findings from real-world video co-presence studies demonstrate that the participants behave more self-aware during video co-presence with a conspecific, irrespective of the conspecific is watching them, the heightened level of self-awareness being pro-social and motivational (Cañigueral & Hamilton, 2019). In contrast, the companion's physical co-presence is in the real world is considered a social distraction, elevating the participant's vigilance levels and requiring additional inhibitory cognitive resources to avoid the attention shifts to companions' presence and focus on the task (Belletier et al., 2019; Sanders, 1981). The higher requirement of inhibitory processing is associated with poorer performance on more difficult tasks that requires higher cognitive resources to complete (Belletier et al., 2019). In the current videoconference experiment, the companion visual presence impact was not significant, potentially easing the attentional burden of the participant, whilst they focus on the task. The same companion-based effect logic, related to cognitive attention-inhibition, can be applied to the findings in immersive MPE. During immersive experience, the participant's self-presence was functional, meaning they was no realistic self-visual representation, potentially lacking self-visual presence-based facilitation. However, because the state of co-immersion with the companion was high, the humanoid companion's visual presence might have been more socially distracting leading to the social inhibition effect only.

The trajectory of the current MPE findings could be explained through the virtual platform's affordances and limitations (Gibson, 2014; Jones, 2018). The videoconference platform enables participant to be realistically seen through a video (facilitating), whilst limiting the sense of sharing the same environment with companion (lack of inhibition due to distraction). The head mounted immersive platform is enabling a sufficient level of virtual co-presence (inhibitory due to distraction), whilst limiting visible self-presence (lack of self-awareness facilitation) due to wearing of virtual headset and poor realistic self-rendering due to technological limitations. This virtual self-and-companion presence level interpretation seems to be straightforward from the perspective of attention and cognitive load theory, however, whilst looking into the AE, the social impact could be driven by more than merely visual features of self and companion.

The AE-driven SFE is elicited by another person's monitoring, and the concerns over companions' disposition towards the performer (Guerin & Innes, 1984). In prior literature, the AE based SFE has been reported without the visual presence of the monitoring companion, elicited merely through the belief that another person is remotely watching the participants perform through a video (Dumontheil et al., 2016; Wolf et al., 2015). The current AE results demonstrated that for videoconference interaction, indeed human-minded (not AI) companion monitoring, impacted participants task performance. Within the immersive platform, monitoring was also impactful, however, the impact was mostly irrespective of companion agency. Similarly, to the MPE, the AE impact was facilitative in video conference and inhibitory for immersive environments. This pattern of results could suggest that the platform type had some influence over the impact, for example it is possible that the lack of self-visual presence in the immersive environment could account for no facilitation results thought AE. However, the platform type and platform specific accordance relating to self or companion presence cannot explain all the results. For example, it is unclear why there was an inhibitory impact of monitoring (AE) in an immersive environment, considering that the distracting physical co-presence with companion should not matter for AE. The platform affordances also do not entirely explain AE based facilitation in videoconference studies, considering the visual aspects of companion, presence of which was non-significant, should not be important for AE. The following paragraphs offer an interpretation of the current findings from the perspective of additive effect of physical interaction environment and the effects based on social interaction platform. It is important to keep in mind that these interpretations are currently merely speculative, theoretically driven by the arousal theories.

The results for the videoconference-based AE demonstrated that monitoring affected participant's performance significantly on RT and marginally for accuracy, irrespective of whether the participant could see the companion, as long as the participant believed that the companion has a human mind. However, unlike the in-lab video-based study (Dumontheil et al., 2016), our AE videoconference-based intervention did not result in SFE. The most reliable significant AE-driven effect within our videoconference-based experiments was the facilitation of easy task performance speed. This result was found for the avatar companion in experiment one and replicated in experiment two during which the effect was shown to be driven by either the monitoring of performance screen-share or participant's self-video presence (not both simultaneously). There were no additional difficult task inhibitory impacts that are expected from the canonical SFE. In the context of MPE, this lack of AE-driven inhibitory effects, could have been attributed to the lack of sufficient companion virtual co-presence, due to limited videoconference platform affordance in transferring realistic state of co-presence. However, as mentioned prior, the companion's visual presence is presumed to be irrelevant for AE-based SFE, as demonstrated by Dumontheil et al., (2016). In the current videoconference-based study, similarly to Dumontheil et al., (2016), the participants were monitored remotely through the video using the same cognitive paradigm (relational reasoning paradigm). One of the differences between the two studies, ours and by Dumontheil et al., (2016) was the physical testing environment. Our videoconference-based studies (experiment one and experiment two) were conducted remotely, whilst the original study in the laboratory setting. This could suggest that the environment in which the testing occurs could also influence the experienced social impact levels. If this is indeed the case, the physical self-presence in the testing environment during the virtual interaction is important. The act of performing remotely, from home, under a context that is controlled by the participant, could have felt less stressful than being monitored in the lab setting. The environmental and cognitive stress related impact on performance has been explored for over a century (Yerkes & Dodson, 1908), with theories suggesting that the medium level of social arousal is motivating (facilitating), whilst higher levels lead to performance detriment (inhibition), especially if the performance is originally sub-par, such as it is on the difficult trials (Hardy & Parfitt, 1991; Strahan & Conger, 1999; Yerkes & Dodson, 1908). Additionally, the SFE literature suggests that the arousal relating to a threat response is detrimental, however, arousal based on the challenge without a threat is facilitatory (Blascovich et al., 1999). Therefore, it seems that the monitoring through a video by a human-minded companion could be sufficient to elicit facilitation arousal, such as by showing the performance or being seen. However, the act of being monitored from the comfort of home, without a physical presence within an uncertain environment, such as the lab, could mean that the stress level did not reach the critical point to affect the performance negatively. This potential lack of impeding threat-related state could also explain why the companion visual video impact was not important when measured in experiment two. As mentioned in the discussion of experiment two (**Chapter 3: Discussion**) the companion could not affect the participants' physical space therefore was less significant. Without companions' physical visual presence being important, the attentional mechanisms could focus on the task, rather than oscillating between the companion and task, using up additional executive and attentional resources.

In contrast to the facilitation without inhibition found in videoconference experiments, the AE within the immersive virtual environment led to inhibition, and interestingly mostly irrespective of companion agency. This inhibition without facilitation trend is currently found in most lab based immersive SFE experiments (Emmerich & Masuch, 2016; Zanbaka et al., 2007). Additionally, the findings that in an immersive environment, the AI-and human-driven visually present humanoid companions are similarly impactful, support the conclusion of the recent meta-analysis (Fox et al., 2014). At first, it is not clear why there was no facilitation found within the immersive interaction, and why did the attentive companion agency matter less in the monitoring impact in an immersive space, but not during videoconferencing. However, it is possible that this missing facilitation was not just due to the companion agency, or the platform used, but, similarly to the videoconference-based finding, a result of real-world testing context interacting with the virtual platform affordances.

It is important to reiterate that, unlike in the realistic self-video presence in a videoconference, the participant's self-visual presence in the immersive virtual environment was only functional (first person without a virtual body), due to being occluded by the virtual headset. Additionally, in contrast to remote testing via a videoconference-based platform from the participant's home, the immersive testing occurred in the lab. Therefore, during the immersive testing, the participant's self-visual presence was lacking within the immersive environment; however, the participants were physically self-present in the lab. The meta-analysis investigating desktop and immersive experiences suggests, that although the immersive experiences have a better capacity to transfer participant away from their real-world environment, both desktop and immersive platforms are still very limited in doing so (Witmer & Singer, 1998). This could mean that whilst in immersive setting, the participants are not fully disengaged from their physical surroundings, i.e., where the participant resides in the real-world when the virtual testing occurs. It is important to note that for safety reasons, in experiment three, the researcher was sitting on the other side of a cubicle – a common practice with research involving head mounted immersive virtual reality. And although the participants were told that the researcher will be working on their own projects turned away from the participant, it is possible that whilst wearing the virtual headset, the participants were apprehensive over this level of physical co-presence in the lab.

The lack of significant AE inhibition, observed in our videoconference-based experiment one and two, was attributed to the potential lower levels of apprehension-related cognitive arousal, due to performing from the safety of the participant's home. Following the same logic, wearing an immersive headset occluding the real-world environment, within a lab setting alongside a potentially physically present researcher, could have heightened participants arousal level due to uncertainty over environment. Considering the uncertainly might have been social presence related, the effect could have been real-world MPE related. This inference could also explain the observation that, overall, the baseline performance in an immersive setting was higher than in the two studies in a videoconference-based setting. The additional arousing act of monitoring could have raised the cognitive apprehension levels from the real-world MPE towards the impeding levels associated with just performance inhibition. As mentioned prior, higher levels of arousal are believed to be more detrimental to the performance (Hardy & Parfitt, 1991; Yerkes & Dodson, 1908). This explanation relating to additional environmental contribution, could suggest an additive effects of immersive virtual and real-world social impact, potentially through accumulative arousal. This explanation is enticing, although we should be cautious in this interpretation as there are many other factors that were different between these studies, and they used different samples of participants.

In addition to the lack of AE based facilitation in an immersive environment, monitoring driven inhibition was mostly irrespective of the participants agency. This effect is different to the AE-driven impact found only for human-minded companions in videoconference-based experiment one (experiment two did not have AI-human contrast). This lack of only human-mind agency impact during the immersive AE, although not unique in immersive literature (Emmerich & Masuch, 2016; Zanbaka et al., 2007), is interesting on its own. This finding could suggest that human-minded companion attentive monitoring is more important when the participant is realistically visually seen themselves. Being visually recognised is suggested to be an important aspect of pro-social behavioural adjustments whilst avoiding social judgement (Joinson, 2001; Seo et al., 2017). The prior immersive research reporting that, although the immersive SFE impact was inhibitory similarly to ours, assigning participants a gender-matched self-avatar identity elicited a human-minded companion, but not AI, agency-based AE (Hoyt et al., 2003). Therefore, it seems that the functional immersive self-visual presence, assigned by our experimental design in experiment three, may not have been sufficient for a meaningful self-representation under human-minded companion judgement. This conclusion is potentially supported by the lack of significant accuracy performance change during immersive monitoring. As in both videoconference experiments, accuracy was facilitated by the MPE, especially self-visual presence (experiment two), the performance speed was however facilitated by either SVP or performance monitoring, but not both simultaneously. Therefore, performance monitoring, rather than self-visual presence, could have driven the mostly RT based immersive AE effect. Future research is needed to validate this interpretation.

If the assumptions for the immersive virtual AE are indeed true, and real-world environment can interact with immersive social setting, then the immersive MPE might have also been affected by the real-world MPE arousal. If this is indeed the case, the humanoid companion presence could have been otherwise sufficiently facilitating within immersive environment, but in the accumulation with real-world lab based MPE, the effect became inhibitory due to heightened accumulative arousal. To validate this assumption, the participants should be tested within an immersive space alone at their own homes, versus in the formal lab setting, alongside a measure of arousal level. Due to there not being eye tracking or psychophysiological measures used in the immersive experiment, it is challenging to declare with certainty whether the virtual MPE was related to social distraction, or the additional arousal driven by the real-world MPE, or both. It is however clear that a humanoid companion's presence within an immersive, but not videoconference, space is impactful.

In summary, it seems that for the SFE facilitation through the MPE and AE mechanisms, there needs to be a sufficient balance between realistic self-visual presence and co-immersion with a companion. Realistic self-visual presence during remote videoconferencing is facilitating, however the companion visual presence was not impactful. There was no inhibitory impact. In contrast, when tested in the lab environment, being immersed alongside a humanoid companion detriments performance. Monitoring is impactful both during videoconference and immersion, similarly to the MPE the effect is facilitative and inhibitory, respectively. Monitoring by human-minded companion seems to more impactful when participants themselves are visible, such as during videoconference interaction.

Additionally, the testing environment impact should be considered when interpreting SFE. In the laboratory setting, the virtual headset occludes the realistic environment. The uncertainty over the lab-based occluded environment and the (potential) physical researcher's presence might generate additional arousal, similar to MPE. For example, the inability to monitor the physical environment when wearing a virtual headset could be perceived as threatful, and thread-based arousal has shown to be detrimental at the SFE level (Blascovich et al., 1999). The opposite effect may arise when participants are tested remotely, from the habitual environments they have control over, such as their homes, lessening the overall arousal stress levels whilst maintaining vigilance on task. The lower medium levels of arousal, without threat, have shown to be motivational leading to better performance outcomes, as measured in SFE (Blascovich et al., 1999). It is important to consider these factors, especially considering the lack of canonical SFE in virtual interaction currently prevails over the studies reporting SFE. Currently, the meta-analyses suggest that most research in real-world SFE (Bond & Titus, 1983) and virtual SFE (Sterna et al., 2019b) do not directly report the social environment in the lab during the occurrence of the SFE social manipulation. Additionally, most virtual SFE studies do not consider the real-world researcher presence or lab condition when reporting their effect (Sterna et al., 2019). The future research needs to be more mindful and explicit of virtual platform affordances and the real-world physical testing context. The only two studies reporting the canonical SFE during interaction with virtual others (Park & Catrambone, 2007, 2021) experiments. In these two studies, the participants were tested as they were real-world present in the lab, alongside a monitoring companion projected on the screen. The participants realistic self-presence was both physically and visually present in their environment, whilst the companion was either projected on a screen or a real person. Again, these findings suggest that sufficient self-visual presence is important, and a higher level of physical self-presence in the testing environment leads to a higher chance of the canonical SFE performance outcome. However, even these two-experiment reported RT SFE only, without mentioning the impact on performance accuracy.

Alongside the SFE, the overall impacts of companion type (**Social Context Effect**, below) were analysed throughout the experiments. The exploratory analyses were conducted to investigate the relationship of companion visual types outside of the context of monitoring and co-presence. The results are provided below.

5.3 Social Context Effects (Overall Companion Effect)

Outside of the search for virtual MPE and AE, experiments one and three investigated the overall impact of performing in the virtual social context of a particular companion. The analyses were exploratory, and results were generally predicted based on the Blascovich (2002) threshold model of social influence during virtual interaction. The Blascovich model predicts that the most humanlike virtual companion, such as a human minded, or most visually human, will be most impactful, whilst AI-minded, or less visually human, least impactful. It was predicted, that overall, the companion impact could be measured in the evaluation of apprehension-related performance impact. We expected the worst performance under the most influential companion due to the participant's apprehension over anticipating evaluation(Cassady & Johnson, 2002; Engert et al., 2013). The detrimental performance was expected because the participants could be more apprehensive about performing under observation by a companion with higher influence than lower. This impact measure was taken irrespective of performance difficulty, the state of monitoring or the perceived momentarily co-presence, rather than as a generally social influence under which the participants anticipated the performance to occur.

The findings from both experiments one and three, which measured the social context impact, found that performance was overall worse under more visually humanlike companions, real-human video (experiment one) and humanoid companions (immersive experiment three). However, there was no consistency relating to the companion agency impact, as the human-minded group performed significantly worse than AI in the video-based study (experiment one) but marginally better in the immersive environment (experiment three).

Based on these inconsistencies, it could be assumed that different platforms translate companion impact differently. Interestingly, this finding supports the results of the meta-analysis on agents and avatars (Fox et al., 2014), which found that under higher immersion, unlike desktop communication, the agency differences become less significant. Based on the findings throughout the experiments in this thesis, the inconsistency in the agency effect could be due to differences in the participant's level of self-presence in the immersive and video environments. The sense of co-presence in immersive space may dominate over the self-visual presence processing of the participant, as the self-visual presence in immersive space was functional and not realistic. The realistic self-visual presence, such as during videoconference, however, might be more susceptible to judgement from another person’s mind. It was indeed reported that participants adjusted their behaviour only when they believed they are identifiable by another person (Seo et al., 2017). It is also worth reiterating that the social facilitation during human-minded companion monitoring (AE) occurred in the videoconference-based experiment, however, the same agency-based monitoring impact was not as clear cut in an immersive environment. This could suggest that when participants are not seen, being seen by another person (human mind) is less important. A more rigorous cross-platform testing is required to validify these assumptions. If the assumptions are indeed true, then the participant's realistic self-visual presence potentially interacts with the social influence levels relating to the companion’s agency. Therefore, virtual platforms need to elicit this realistic sense of self to have an expected outcome. Indeed, when participants are given even a rough visual identity level (gender-matched avatar) in an immersive space, the monitoring by avatar but not agent companions is impactful (Hoyt et al., 2003).

Without further testing of self-visual presence contribution, the social context effects results in the current two experiments suggest that the visual attributes of virtual companions seem to be the most reliable effect of influence cross-platform with the more humanlike companion being most impactful. Contrasting the two virtual interaction theories mentioned in this thesis, the ethopoeia theory (Nass et al., 1994; Nass & Moon, 2000) and the threshold model of social influence (TMSI: Blascovich, 2002), the level of social influence observed in the current studies is evident more of the ethopoeia theory rather than TMSI. The TMSI argues that overall, the companion human mind (agency) will be most impactful, dominating over the companion’s human-like visual realism. Whilst the ethopoeia theory suggests that the realism of virtual companions, rather than their agency, dominates the social influence effects. This was indeed the case for the immersive environment, where humanoid companion presence was significantly affecting the participant's performance, in contrast to the non-humanoid social presence and when the companion was not visually present. In contrast, when testing overall social context effect (main effect of different companion) in videoconference setting, the result showed that companion’s human-mind agency was most impactful, seemingly supporting the TMSI theoretical approach. Although, the social context effect in the videoconference-based study does not necessarily negate Nass’s theory, as the most impactful companion was also the most realistic looking due to being a real person’s live video. The support for Blascovich's (2002) theory in the videoconference experiment comes from the AE results in experiment one, where companion agency impact was present in the human-mind companion, but not for the AI-agent. However, future studies should design and test the contrast of companion mind (human, AI) and virtual body (realistic, virtual, etc) in videoconference platform, in a manipulation similar to the immersive experiment three. More research needs to be conducted contrasting Blascovich and Nass’s theories, with consideration of the perceived self-visual presence of the participant and clear separation of the companion’s virtual mind and body.

To summarise, it seems the social context effect is affected more by the human-minded companion’s agency when participants themselves are seen as they perform, however, the companion more realistic humanlike form is most impactful when the participant is co-present but are not visually exposed.

5.4 General Discussion

In summary, the answer, to a question of whether the SFE can be elicited through the videoconference-based interaction or virtual immersion, is potentially yes, but the process of elicitation might be more nuanced.

The main goal of this thesis was to investigate the virtual SFE. Previously there was conflicting evidence on whether the SFE can be reliably elicited in virtual spaces, and which virtual human companionship, for example, agent or avatar, is sufficient to elicit SFE. The current thesis proposed that investigating the virtual SFE eliciting it though two distinct mechanisms resulting in SFE, the MPE-m and AE-m, could illuminate the main drivers of the effect. The results of the three experiments presented in this thesis have elucidated several potential factors relating to why the virtual SFE are so elusive. From the results, it seems that the virtual platform used, and its affordances, have an important part when it comes to virtual SFE, supporting the literature review (Oh et al., 2018) and results of a recent meta-analysis (Fox et al., 2014) on virtual interaction. However, the real-world testing context, such as whether the study is tested in the lab or remotely, can affect the results.

We tested virtual SFE by using a cognitive task relational reasoning paradigm, which in real world testing has resulted in a canonical SFE effect (Dumontheil et al., 2016). Overall, we found that videoconferencing was facilitating on the task, both for MPE and AE. The facilitation was interpreted to be driven by the realistic self-visual video presence of participants' live video. The lack of inhibitory effect of the MPE could be associated with the lack of sufficient level sense of physical co-presence with the companion. The lack of inhibition through the AE route could be associated with the lower levels of cognitive apprehension related to threat arousal, due to being tested remotely from the comfort of participants' homes. In prior literature, the medium levels of arousal are associated with facilitation, whilst higher levels with inhibition (Hardy & Parfitt, 1991). In contrast to videoconferencing, the immersive experiment (experiment three) results for MPE and AE were inhibitory. The detriment resulting from the immersive MPE was interpreted as social inhibition from a humanoid co-present companion. The inhibition for AE, found to be irrespective of companions' visual presence, was interpreted as a potential response to additive higher-level threat-related arousal, between the real-world environment and the act of monitoring, experienced during immersion. The assumption was that because the virtual headset occluded the participant's ability to monitor their real-world surroundings in the lab, the participants might have felt exposed and uncertain of their real-world environment. This additional state of vigilance could be associated with real-world MPE adding up accumulatively to the immersive AE. The impact of this effect also on the immersive MPE should not be ruled out.

Based on these findings, two main general factors could explain the pattern of effects in the prior virtual SFE literature, one relating to virtual platform affordances and the second to consideration of the real-world environment in which the virtual testing occurs. Arguably, for the canonical SFE to occur, there should be a sufficient level of virtual self-visual presence and co-immersion with the companion. Importantly, the testing environment should control for the real-world confounds, such as other people's physical presence within the environment, to avoid potential additive effects. Based on the current results from testing the MPE and AE mechanism, and the social context effect analyses, it seems that the models of virtual cognition, such as the Blascovich (2002) threshold model of social influence and Nass's theory of ethopoeia (Nass et al., 1994; Nass & Moon, 2000), can only predict companion impact when the platform type and related affordances and the real-world physical testing environment are taken into account. For example, when testing virtual SFE, it is important to understand what is the physical environment in which the participants engage in the virtual interaction and how does virtual platform obstruct or amplify the physical environment. Future studies should contrast the two theories while accounting for the factors such as, self-visual presence, immersion, testing environment, and companion agency and visual type.

The next sections discuss the limitations of the current series of experiments followed by the proposed solution to tackle these limitations (**Limitations and Ways Forward).** The final sections will discuss the potential real word implementation of the current findings **(Real World Implementation)**, followed by a **Take Home Message** and **Conclusions** sections.

5.5 Limitations and Ways Forward

The current findings are interesting; however, the results raise more questions and require further replication. To inspire further experimental designs, it is important to acknowledge that the current approaches had their shortcomings and limitations. Some could be considered confounding, some merely a cautionary for further experiments for virtual SFE.

First, as mentioned in this discussion chapter, one of the most important confounds in the current experiment was the mere presence of the researcher in the same physical space during immersive testing in experiment three, but not in experiments one or two. Although the effect is interesting, and it replicates, and potentially explains the majority of the immersive virtual literature in lab inhibitory findings, the true immersive impact of immersive virtual companion was not measured in isolation from the real-world presence of the researcher. Therefore, this finding reflects the impact of someone interacting in an immersive space with a virtual human, whilst being in the real room with someone else, rather than merely in the immersive virtual presence of the companion. Considering that many immersive experiences can occur within a busy social world, such as in arcades or training simulations, this finding is important as a standalone result. However, considering the videoconference-based studies were tested from the isolation of participant's homes, remotely, the conclusions currently drawn in the discussion, whilst interpreting the effect in relation to the different virtual platforms and testing environments should be taken with preliminary caution. Future research should take on board the potential impact of real-world co-presence alongside immersive presence and test MPE and AE using a cross-platform approach. Preferably, the approach should test participants remotely, from their own homes, at different platform levels, and contrast the effect with identical lab-based conditions, with and without the real-world companion. Establishing a direct causal real-world environment x virtual environment social presence interaction would elucidate the potential of the additive vigilance arousal effect. Additionally, the overall experience of performing the task in immersive space can be unusual and lead to connive overload. Therefore, future testing should consider contrasting participants who are more experienced in immersive spaces versus participants to whom the experiment is novel. The worse quality and resolution of the immersive environment could also potentially add additional cognitive load, therefore a baseline state of performance, irrespective of social presence should be measured against real-world setting.

Another confound in the immersive setting cold be that the participants did not really feel like they were realistically represented in the immersive space. The participant's self-visual presence could have been more realistically representative of the participants, due to technical limitation at the time that was not possible. However, if we could assign participants an avatar representing their identity more, we could have potentially elicited the immersive agency-based AE facilitation, similar to Hoyt et al., (2003). However, as discussed in **Chapter 4: Introduction** , assigning participants self-avatars an identity that might not reflect the participant's own, could add more confound to the results. Therefore, the best solution to this would be to use participants' avatars, which they already identify with in the immersive social environments, such as in VRChat and AltspaceVR. Unfortunately, during the time the current immersive study was originally conducted, the immersive social platforms were not yet common enough for most people did not have access to home-based immersive reality headsets. It is now possible to test remote immersive SFE impact with greater ease.

Of course, the other main limitation of the current experiments is that the data reported is merely behavioural. Although the purpose of the current studies was to solidify the factors of the MPE and AE for further neuroimaging and attentional exploration, the lack of physiological data makes certain effect interpretations more challenging. For example, the gaze data could have either supported or negated the humanoid companion's presence as a distraction or mere arousal assumption. Although we currently are video coding the non-verbal behavioural data in a videoconference-based setting, more systematic physiological data acquisition could aid in unravelling current effects.

Alongside the software and physical environment limitations, several additional considerations should be assessed when interpreting the current data from the three experiments. For example, although the significant findings reported in the current experiment seemed to be well powered, with the least medium effect sizes, the error bars within the conditions are still fairly large. There are two possible explanations for these observations, one, it is possible that the task difficulties were not perceived consistently as easy or difficult between the participants, and two, there could have been individual differences in social processing which interfered with the effect.

Firstly, although there was significant task difficulty difference between the easy and difficult tasks, the data throughout the three experiments was negatively skewed, with some participants scoring within the 90 percent margin even on difficult task. The difficult task kurtosis was flatter and more spread than easy task, suggesting that there was a large variation in how participants perceived the task difficulty. It is possible that for many participants the difficult task was not difficult enough to elicit discomfort and drop in task performance. For the easy task, the accuracy data was also negatively skewed suggesting potential ceiling effect. Therefore, although the RRP elicited canonical SFE in a previous real-world experiment (Dumontheil et al., 2016), it is possible that participants in the tasks included in my thesis found the tasks too easy at both task difficulties. Whether this observation is due to platforms used, idiosyncrasy of our participants groups or the task itself, is unclear. Therefore, some effect might have been skewed merely due to task difficulty unique to the RRP task chosen in my studies. Although the task inhibition and facilitation levels did vary based on platforms used, the three experiments should be replicated with a task more representative of participants abilities. Of course, as mentioned prior, participants' perceived abilities for task performance can be also subjective. Therefore, a special care should be taken when selecting the task. To keep the paradigm more ecologically valid, one solution would be giving participant a novel task with no instructions and contrasting it to performance on a known daily task at medium difficulty.

When considering the individual differences in social processing, it is possible that some of the current effects may have been masked due to the variability within the participant's groups. This variability could be driven by several factors. First, the participant's beliefs about whether the virtual AI character can mentalise or judge them might vary. However, when testing, we directly asked the participants about their beliefs about the companion at the end of the study. The level at which the participants were willing to admit they did not feel apprehension under the AI-companion presence, and what that apprehension might mean to them might naturally vary. To account for this personal disposition about AI interactions, the participants should potentially be grouped based on their beliefs about AI abilities and contrasted. Although the current three experiments did not check for participant grouping on their disposition, all the studies made sure the participants knew which companion they are interacting with. The current experiment's inclusion criteria were strict, only participants who believed that the AI companion was indeed an AI-driven agent, and the avatar companion was indeed human-driven, were entered into the analyses. Although participants' individual differences in perception of the AI-mind might have explained some variability, it was not the main purpose of the current study. Future research should look into group differences based on people’s perceptions and beliefs about AI abilities. Some research already suggests that beliefs about AI-ability to judge performance can lead to changes in participant behaviour.

Additionally, to the individual difference in perception of AI-minded companion abilities, there are other aspects of individual differences that can explain the variability in the current data. These individual differences could be related to social processing overall, and the possible neurodivergence in social processing from a neurotypical social profile. For example, the participant's individual traits at sub-clinical levels, such as extraversion and social anxiety, already explain some of the SFE variation (Uziel, 2007). Further evidence suggests that participants with social anxiety and autistic individuals can process social situations differently. We have currently gathered individual differences questionnaires from all three studies, with the hope to unravel some of the trends hidden within the current error variability. The sample sizes are currently underpowered for a meaningful conclusion; however, hopefully further studies will explore these effects in more detail.

Finally, it is important to state that with the emerging new technologies and the limitations of virtual environments, other virtual reality environments may convey self-visual presence and companion co-presence in a more impactful and natural way. For example, augmented reality (AR), can transfer digital companions within a participant's personal space, without occluding the real-world environment. During this level of interaction, the participants are also realistically self-visually and physically present. Currently, the early research coming out on the SFE of AR is promising (Miller et al., 2019; Mostajeran et al., 2022). Additionally, to augmented reality, there is an option of mixed reality, such as the virtual cave. In which the participants can be immersed in the virtual environment as their realistic selves, with either real-person or virtual human joining them either remotely or in the lab. Given the new technologies, the possibility to discover the optimal meaningful level of virtual co-presence becomes easier. However, as our current findings might suggest, the level of real-world arousal and virtual presence arousal can be accumulative. Therefore, whether more social co-presence is always the way forwards, should be considered when thinking about the further implementation of these additional layers of digital reality in the real-world setting.

5.6 Real World Implementation

As technology progresses, so do our ideas about how these new tools can be applied in our daily lives. Currently, many people cannot imagine their lives without the ability to videoconference with their loved ones, or video calling for a quick work meeting. Social media engineers are already designing the future of social interaction in the form of immersive offices and augmented meeting rooms. However, it is important to remember, that any communication technology and its affordances, like every other tool, should be utilised in industry when it is most practical. Therefore, generalising impacts from the current studies should be done with care, especially when we are heading towards the reality in which augmented and virtual interaction tools are used for wellbeing and education purposes and within more vulnerable populations.

The notion of well-being-oriented interaction platforms would be that the social communication platforms are developed with their user's wellbeing in mind. The factors that should be considered would focus on decreasing the cognitive load of the virtual interaction, for example through less noisy platforms, more natural non-verbal communication, and social transcription aid when needed. Informed by research, the levels of communication should be more user friendly depending on the social needs and abilities of the virtual communication users. The scope of how wellbeing-based platforms can also help also socially neurodiverse population is beyond the current thesis, so I decided not to elaborate on this topic further. However, as we learn more about the social neurodiversity both in real-world and virtual communication, it will become clear that the technology can also positively augment the social experience of non-neurotypical population.

The current series of studies focus on the neurotypical population. Specifically targeted at the education and work sectors, where real-time high-intensity cognitive performance matters, therefore implications from our study should not be automatically extended to other sectors, particularly the health sector.

The current findings can be applied to the development of more human-wellbeing-centred virtual and mixed reality work and education environments. One of the most important aspects is the consideration of self-visual presence in the environment and the context in which virtual interaction is used. For example, during remote teaching, it might be overall beneficial to ask the student to turn on their video cameras. This can be done without the need for the students to share their screen-share, as their self-presence alone should be motivating enough for them to more vigilant in the virtual classroom. During this time, the teacher's visual presence might not always be necessary, as long as students are aware that they themselves could be seen. This level of video-based vigilance seems to be facilitating enough to be motivating, even on more difficult tasks, yet not overly stressful to detriment students' performance. This level of self-video mere presence can be used for example when administering remote tests. The same logic can be applied to work environments, especially for routine repetitive tasks. The additional level of vigilance of being seen on camera, might provide an additional boost to persevere through more boring and repetitive tasks. As mentioned in the introduction, of this thesis this practice was already anecdotally applied during the Covid-19 pandemic, with individuals stating that mere-video co-presence with their colleagues keeps them more focused on the "boring" tasks.

Interestingly, this level of visual co-presence seems to not depend on the companion's mindedness, so theoretically, the participant could be merely self-visually video present with a remote virtual AI-agent in the messenger, and still experience this facilitation. However, when it might be important to maintain a more pro-social behaviour associated with judgement, the videoconference companion should be human minded.

It is more difficult to draw conclusive findings from the immersive environment, due to the possible confounding effect of researchers' real-world presence. However, from the current findings, the immersive training simulators using virtual humans as trainers should be used with caution, when the training occurs in a room with other people. The potential additional effects of the real-world and immersive presence could affect trainees' performance negatively. However, when training for more highly arousal-based scenarios, in which trainees would need to make a quick decision under higher levels of stress, inducing higher apprehension levels could be beneficial to replicate real-world stress arousal states. These higher levels of vigilance might also be used in action-based entertainment, when the potential of real-world impact and virtual co-presence could create an additional state of uncertainly and vigilance, without the concern of performance impact. Interestingly, based on the current findings, the agency of the companion does not significantly matter in this case. As long as the companion is humanoid, they can be as equally socially distracting in the immersive space. However, considering the immersive space itself can be distracting, meaningful learning within an immersive headset from a virtual teacher might be more challenging. It could be especially challenging if done in the real-world classroom with other students who are not virtually immersed as well. If the immersed pupil does not feel comfortable and safe within their physical environment, the immersive experience could be distracting and detrimental to immersive learning attention.

This of course if the immersive reality platform cannot fully disengage the user from the environment.

Additionally, the effects of platform affordances, virtual companions and the potential states of vigilance these encounters might evoke should be considered when testing on a more vulnerable population. For example, when testing people with anxiety disorders. Extra care should be taken when immersing vulnerable population within the immersive space in an unfamiliar setting. Considering that that immersive platforms do not currently fully disengage the participant from the real-world environment, the researcher's mere presence in the real world could be a reminder of safety, for example when using an immersive setting as a treatment for phobias (Witmer & Singer, 1998). However, depending on the participants prior beliefs, being unable to monitor the real-world setting might elevate state of vigilance and stress to detrimental levels. It is also important to note that videoconference-based presence did not seem to detriment participants performance in the study, although there was a significant motivation. Therefore, using a video-based method with patience who might feel more apprehensive of in-person interaction, could be less anxiety provoking intervention, as patience might feel more in control in their own environment of choosing.

It is important to reiterate that although the wellbeing interventions are discussed in the above chapter, the current findings are directed at work and education fields, with some implementation in entertainment. Although there is a growing interest in using virtual platforms and assistants in the health and wellbeing sectors (Fiske et al., 2019), the current findings should not be directly generalised to these sectors. For example, when it is stated in the thesis that the presence is meaningful, it does not imply that there is an emotional, compassion, or wellness-based state relating to the effect, rather that there is a cognitive or physiological appraisal which affects the participant's performance threshold. In the short-term testing, we indeed found task facilitation or inhibition, however, we did not test the emotional effects, or long-term effects, of these experiences. When discussing the possible benefits of AI agents in emotionally supportive settings, practitioners should still be sufficiently sceptical, reflecting on the current evidence of lower levels of educational and therapy outcomes during the COVID-19 pandemic, explained by the lack of meaningful in-person connection (Aboujaaoude et al., 2021). It is also not clear whether the positive effects experienced short-term, such as facilitation, leads to cognitive fatigue when experienced long-term, see zoom fatigue (Bailenson, 2021). Future research should extend the current finding on virtual companion impacts, on different levels of virtual presence, in sectors in which authentic human compassion and support are required for health and emotional outcomes (Kothgassner et al., 2019).

5.7 Take Home Message

The thesis attempted to disentangle the virtual SFE, to understand the discrepancy in the literature relating to the impact of virtual humans on different virtual communication platforms. From the current findings, it seems that in the virtual realms, where the presence of the self and others can be occluded, these effects are fragile and require a sufficient combination of self-presence and co-immersion with the companion to emerge. The real-world environment, in which the virtual experience occurs, is also an important factor to consider when testing and interpreting the results.

The first two experiments reliably elicited facilitation under a realistic level of video self-visual presence alongside a remote companion (experiments one and two). The experiments were tested remotely whilst video conferencing with participants from their homes. Experiment two showed that here was no impact of companion visual presence when tested remotely through videoconference platform. The in-lab immersive experiment (experiment three) demonstrated performance inhibition, under less realistic self-presence but higher immersion with the companion. The effects of experiment three could be a combination of in-lab-based MPE and immersive MPE. Irrespective of the direction of the result in the immersive study, the humanoid companion co-presence was impactful. Although the current experiments have not yet reached the appropriate combination of self-visual presence and co-immersion with a companion, for the canonical SFE to emerge, the results and their interpretation explain the complexity of these seemingly simple MPE and AE mechanisms. The **Results Interpretation and Discussion** section of this thesis highlights the importance of considering the virtual platform affordances, such as immersion and self-visual presence, and the real-world testing environment, whether the participant performs remotely, alone, or in the potential real-world presence of others. These considerations should be taken into account, and stated clearly, both when designing and reporting future virtual effects, and interpreting the results.

This research has factored out four important factors that might contribute to meaningful virtual SFE impact: the realistic self-visual presence of the participant, the humanoid visual appearance of the companion, and appropriate immersive virtual co-presence achieved through virtual reality, and the real-world environment in which the testing occurs. The impact of these levels needs to be tested further beyond just the behavioural measures, focusing on gaze and functional data.

Importantly, this thesis has merely factored out the levels which might interact with each other to create a more tangible social impact. By unveiling the level of complexity, even at these baseline levels of virtual second person interaction, hopefully, the findings will contribute to a broader understanding, and more precise models, of virtual social cognition. This is especially important now, as the technology advancements and communication requirements are transcending the conventional real-world interaction, blurring the lines between what, and who, is real and virtual.

Conclusion

The three experiments in this thesis tested whether investigating SFE through its mechanism, the AE and MPE, would explain the discrepancies in the current virtual SFE literature. The prior literature findings were unclear on whether SFE can be elicited by avatar or agent companion and at which virtual interaction level. The current result showed that accounting for the AE and MPE can indeed explain some trends found in earlier research. As predicted, the attentive monitoring (AE) based SFE impact is mostly driven by human-minded companion, such as avatar, but not significantly by an AI companion, such as agent. Importantly, monitoring by human-minded companion seems to be important when participant is realistically self-visually present, such as in video. The MPE however can be elicited irrespective of companion agency type, as long as they are humanoid. The companion humanoid presence is impactful only under sufficient virtual co-presence, such as immersive environment. The performance outcomes were not the canonical SFE, but of facilitation (video) or inhibition (immersive), a dominant trend in the current virtual SFE literature. This trend can be interpreted from the perspective of virtual platform affordances, such as whether participant is self-visually present in the interaction and the level of co-immersion between participant and companion. Additionally, the real-world testing conditions, such as whether testing occurs remotely from participants homes or in the laboratory affects virtual performance outcome. When testing virtual human impact in the future, we advise that researchers ensure that factors such as self-visual presence, platform affordances, and real-world testing environment are accounted for, and reported clearly, in order to understand the effects further.

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Appendix A

Chapter 2 Appendix. A series of planned *t*-test comparisons for the Audience Effects (AE) hypothesis two (***H2***), with a mean (*M*) and 1 Standard Deviation (*SD*).

Table A1.

*AE percent Accuracy descriptive (M and SD), t and p statistics for planned (not corrected) follow up contrasts within each Companion group separately. * p = < .05*

Companion	**Difficulty**	**Not Monitored** *M (SD)*	**Attentive** *M(SD)*	***t** (1,17)*	***p***
Real Human	**Easy**	89.17 (8.91)	90.56 (12.11)	0.67	.51
	Difficult	72.50 (13.88)	78.61 (19.46)	2.02	.06
Avatar	**Easy**	94.58 (4.04)	90.56 (7.45)	1.91	.07
	Difficult	80.00 (15.58)	80.56 (18.54)	0.23	.82
Agent	**Easy**	94.02 (3.85)	92.78 (6.46)	0.71	.49
	Difficult	87.22(6.91)	86.39 (12.22)	0.35	.73

Table A2.

AE RT descriptive (M and SD), t and p statistics for planned follow up contrasts within each Companion group separately.

Companion	**Difficulty**	**Not Monitored** *M* (*SD*)	**Attentive** *M* (*SD*)	***t*** *(1,17)*	***p***
Real Human	**Easy**	1564.39 (267.80)	1511.06 (329.45)	0.89	.39
	Difficult	2073.27 (402.02)	2020.95 (402.55)	0.79	.44
Avatar	**Easy**	1393.57 (320.62)	1269.01 (299.76)	2.68	**.016***
	Difficult	1867.36 (397.15)	1854.19 (390.13)	0.20	.84
Agent	**Easy**	1289.51(265.35)	1291.23 (293.29)	0.04	.97
	Difficult	1823.14(513.30)	1766.64 (504.78)	0.76	.46

Appendix B

Breakdown of a Three-Way ANOVA

Appendix for Chapter 2. Additional figures represent means and 1 SD per each Three-Factor ANOVA level separately.

Figure B1: *Figure B1 (A) and (B) illustrate a breakdown for all conditions means (M) and 1 Standard Deviation (SD) of the three-way ANOVA: Companion x 3 Observance x 2 Difficulty, for Accuracy (A) and RT (B) separately.*