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Supplementary Information

Estimation of capacity scores

Following Owen, Koster and Derakshan (2011; see also Pashler 1988; Cowan 2001; Vogel & Machizawa 2004), our capacity score formula was obtained by combining the following equations:

$$\mathbf{H} = \frac{\mathbf{k}}{\mathbf{S}} + \left(\frac{\mathbf{S-k}}{\mathbf{S}}\right)\mathbf{g} \qquad \text{Equation 1}$$

$$\mathbf{CR} = \frac{\mathbf{k}}{S} + \left(\frac{\mathbf{S-k}}{\mathbf{S}}\right)(\mathbf{1-g}) \qquad \text{Equation 2}$$

Where H, CR, S, and g are respectively the hit rate, correct rejection rate, size of the array being displayed and the guessing parameter. When Equation 1 and Equation 2 are combined and rearranged by *k* we obtain the estimate of a participant's capacity:

$$\mathbf{H + CR = 2}\frac{\mathbf{k}}{\mathbf{S}} + \left(\frac{\mathbf{S-k}}{\mathbf{S}}\right) \rightarrow \mathbf{k = S[H - (1 - CR)]}$$

$$\text{Since } \mathrm{FA} = 1 - \mathrm{CR} \qquad \mathrm{k} = \mathrm{S}(\mathrm{H} - \mathrm{FA}) \qquad \text{Equation 3}$$

Assessment of capacity limits with a standard set-size in individuals with low and high levels of inattention

IB individuals are commonly associated with a low working memory and processing capacity (Hannon & Richards, 2010; Richards, Hannon, & Derakshan, 2010; Richards, Hannon, & Vitkovitch, 2010; Papera & Richards, 2016) and this may suggest the use of smaller set-sizes in a change detection task (i.e., smaller than the standard 4+/-1 visual working memory span; see Sperling, 1960; Posner, 1969; Scarborough, 1971; see also Vogel, McCollough, & Machizawa, 2005; Cowan, 2001) to assess visual working memory.

Since Jost, Bryck, Vogel and Mayr (2010) showed that smaller set-sizes (e.g., 1, 2 or 3) might underestimate capacity (and therefore associated measures of selection and storage efficiency), this pilot study used set sizes 2 and 4 to determine the capacity limits of this population of individuals. If capacity was reached at set-size 2 but exceeded at set-size 4, this should result in a drop in mean amplitudes for both the latencies of the N2 and CDA for set-size 4 (see for a justification Vogel & Machizawa, 2004), resulting in similar amplitude for set-size 4 and 2.

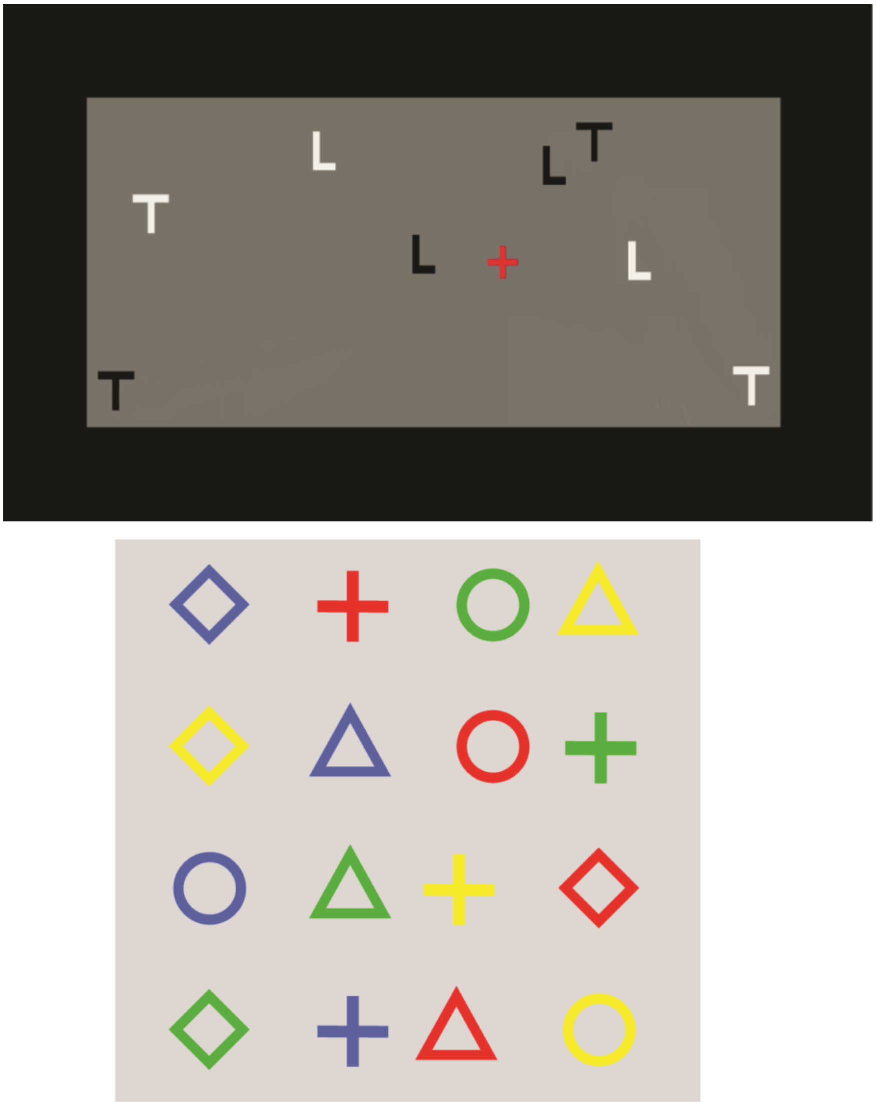
Participants

Twenty-eight healthy individuals were recruited for course credits. Thirteen were excluded due to meeting exclusion criteria (see next section), resulting in a final sample of 15 subjects (mean age: 28.26 ± 9.22; 11 females). All participants had normal or corrected-to-normal vision and were naïve about the purpose of the research. The experiment was carried out in accordance with institutional guidelines and approval by the department ethics committee.

Stimuli

The IB task was programmed in MatLab™ and based on the video clip of Simons (2003) to resemble the dynamic IB task described in Most, Simons, Scholl, Jimenez, Clifford and Chabris (2001). It comprises a moving array with two sets of letters: white Ls and Ts, and black Ls and Ts. The video begins with a still frame for about 8.5 s showing the positions of the stimuli before they start moving on a grey background and bouncing off the black border of the display (see supplementary Fig. 1 top panel). Subjects are told to track the white letters and count the number of bounces (13 hits overall; total running time 30 s). A red cross appears 15 s into the video moving from the right visual field to the left for approximately 12 s. At the end of the video, participants were asked to report the total number of bounces and then they were asked if they saw anything unusual during the video. If they reported not seeing anything unusual, they were prompted and asked if they were sure. All responses were noted.

Next, a recognition test consisting of a set of shapes (including the unexpected stimulus; see supplementary Fig. 1 bottom panel) was administered and participants were asked whether they saw any of the shapes whilst they were performing the primary task. Subjects who presented reports containing partial featural information about the unexpected



Supplementary Fig. 1. IB Task (based on Simons, 2003) where four black and four white Ls and Ts move randomly in a linear manner around the display and bounce off the edge of the display. Subjects were asked to monitor the white letters (targets) and ignore the black letters (distractors), and silently count the number of times the targets hit the edge of the frame (13 hits). After 15 s, a red plus sign appears at the right hand side of the frame taking 12 s to traverse across the display and disappear at the left hand side. Bottom panel shows the following recognition task.

stimulus (e.g. a red circle, or a green cross, etc.) were not included in the study. Participants failing to report the unexpected stimulus (i.e., red cross) are deemed to be IB subjects and those who did indicate the red-cross on the panel in Supplementary Fig. 1 (bottom) were deemed to be Non-IB. The change detection task comprised three conditions: set-size 2 (2 targets; 2T0D), set-size 4 (4 targets; 4T0D) and set-size 4 (2 targets and 2 distractors; 2T2D). The task started with a practice block to familiarise the participants, followed by a total of 720 trials (240 trials per condition with 50% of them reporting a single change in orientation for one of the items), divided into 5 blocks of 144 trials each. Finally, the same AOSPAN task used in the main experiment was administered.

Data Acquisition, analysis and procedure

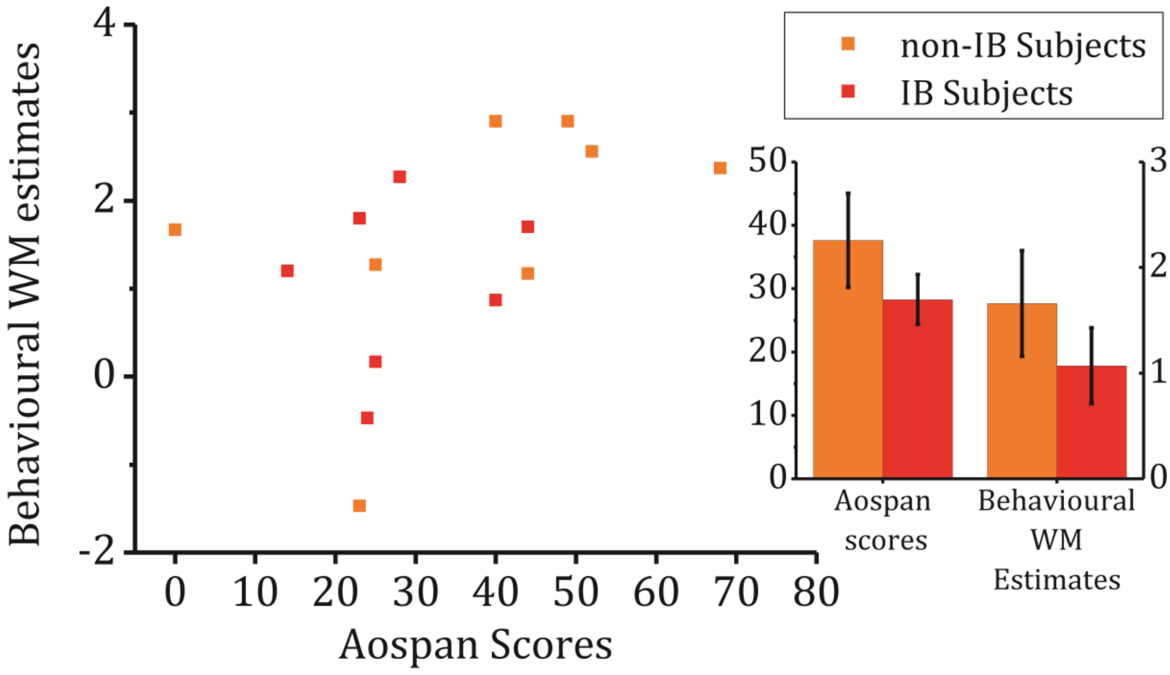
The same data acquisition as for the main experiment was implemented. The same ERP exclusion criteria as the main experiment were used, leading to the following number of accepted trials: 201±32 for the set-size 2 condition, 193±38 for the set-size 4 with distractors condition and 163±40 for the set-size 4 without distractors. Overall 90% of the accepted participants had at least 113 trials per condition. The remaining 10% had trials ranging between 76 and 144 per condition. For the IB task, participants who over- or under-estimated the number of counts at the primary task (i.e., <9 or >16 counts) were excluded from the study. This led to the exclusion of 12 participants (9 subjects for excessive artefacts, 2 participants for over/under estimating the number of counts during the IB task, 1 participant for underestimating and providing an unclear IB task report). For the ERP recordings, analogously to the main study, a regional analysis based on the largest magnitude of modulation was adopted, therefore activity in the posterior regions were assessed using the pairs P3/4 and P7/8.

Participants first performed the AOSPAN test followed by the IB and recognition tasks. Finally, the change detection task was administered. The same experimental apparatus was used as for the main experiment, apart from the following differences. Since set-sizes were higher, both memory and test arrays were displayed in a larger portion of the screen: within two display areas of 4.29°×5.36° at 80 cm viewing distance, and 2.86° away from the centre of the screen for both the right and left side. The size of the rectangles was 1.22°×0.64° both for red and blue items. Time presentation for the memory array was set to 200 ms.

Results

The IBs had non-significantly lower WMC scores as measured by AOSPAN than the Non-IBs ($\bar{x}_{\mathrm{IB}} = 28.28$, $\mathrm{SE}_{\mathrm{IB}}$ =3.92; $\bar{x}_{\mathrm{NIB}}$=37.62, $\mathrm{SE}_{\mathrm{NIB}} = 7.43$; $t(13)$ =1.06, p =.15; one-tailed). This was consistent with the estimates of the WMC based on hit and false alarm rates in the change detection task, which did not differ between the two groups ($\bar{x}_{\mathrm{IB}} = 1.07$, $\mathrm{SE}_{\mathrm{IB}}$ =.36; $\bar{x}_{\mathrm{NIB}} = 1.66$, $\mathrm{SE}_{\mathrm{NIB}} = .50$, $t(13)$ =.92, p =.18; one-tailed; see Fig. 2A). However, a marginally significant correlation was found between the AOSPAN scores and the WMC estimates ($r(15)$= .44, p=.05, one-tailed; Fig. 2A), showing that the estimates of WMC based on the change detection task performance may be used reliably to estimate the number of items stored in VWM.

For the IB task performance at the primary task (i.e., number of counts) was assessed and found to be different across groups ($t(13)$ =2.02, p <.04; one-tailed), suggesting that

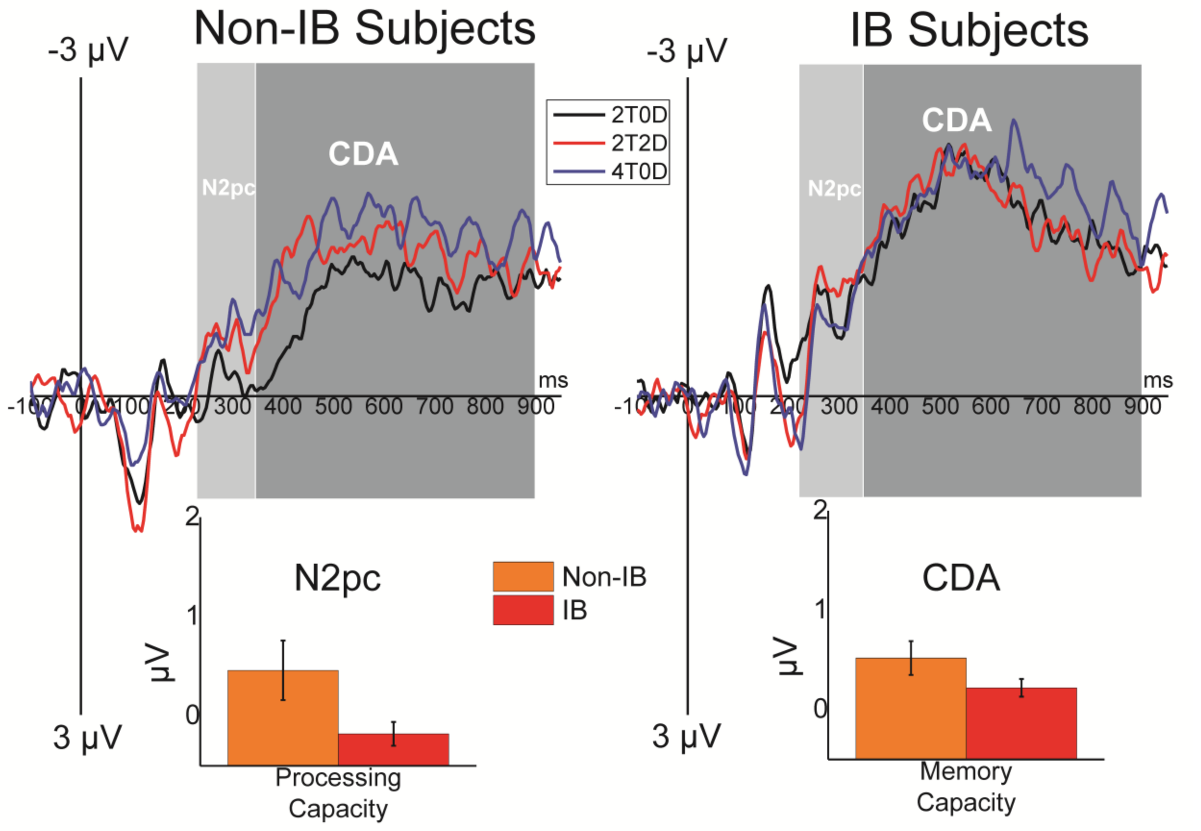


Supplementary Fig. 2. Scatterplot showing the correlation between AOSPAN scores and the behavioural estimate of the working memory capacity based on the change detection task objective performance. Inset graph: mean differences between the low and high inattention groups for the two measures whose correlation was assessed.

Non-IB participants can perform better at the primary task ($\bar{x}_{\mathrm{NIB}}$=12.63, $\mathrm{SE}_{\mathrm{NIB}}$=1.06) and still be able to notice an unexpected stimulus when compared to IB participants ($\bar{x}_{\mathrm{IB}}$=11.29, $\mathrm{SE}_{\mathrm{IB}}$= 1.49). However, the mean difference was small (i.e., 1.33 more counts for Non-IB subjects), and did not appear to influence the likelihood of noticing the unexpected stimulus (i.e., although IB participants have poorer performance, they still fail to notice the unexpected stimulus).

Estimates of processing and visual working memory capacity were calculated using the mean amplitudes in the latencies of interest (see shaded areas in Fig. 3) and used to carry out t-tests to assess differences between the two groups. Processing capacity scores during the N2pc latency were significantly different across the two groups ($\bar{x}_{\mathrm{IB}} = -.18$, $\mathrm{SE}_{\mathrm{IB}} = .12$; $\bar{x}_{\mathrm{NIB}}$=.46, $\mathrm{SE}_{\mathrm{NIB}} = .30$; t(13)= 1.82, p<.05, one-tailed), suggesting that compared to IB participants, Non-IB subjects allocate more resources for the selection of a higher number of targets (set-size 4 without distractors; see Fig. 3A-B), whereas IB subjects appear to have exhausted their resources. N2pc amplitudes for set size 2 are more negative for IB than Non-IB participants and similar to the amplitudes for set size 4 without distractors, suggesting that IB participants are already using most of their resources to select 2 items.

However, although Non-IB participants may be able to select and enhance all the target items in the array, ERP-based WMC scores suggests that they may not be able to store all the target items for set size 4 without distractors. No differences were found across the groups for selection/storage efficiency and for ERP-based visual WM capacity scores (all p>.08, one-tailed).



Supplementary Fig. 3. Plot of the grand averaged ERP difference waves for the contralateral minus ipsilateral activity time-locked to the presentation of the memory array across the electrode pairs P3-4 and P7-8 and divided between the two experimental groups: Non-IB (part a) and IB subject (part b). Inset graphs: differences across groups for the four assessed estimates based on the mean amplitude in the latencies of interest (shaded in the ERP plots).

Conclusions

Overall results from this preliminary study suggested that participants' capacity (as measured by the CDA) may be exceeded for set-size 4, since it is remarkably similar to set-size 2 for IB individuals. This appeared to be the case for Non-IB subjects as well. A set-size exceeding their capacity such as an array of 4 target items may have caused a drop in the mean amplitudes (see for instance the findings inVogel & Machizawa, 2004), hence presenting similar mean amplitudes for set-size 4 and set-size 2. Although their processing capacity scores were significantly higher than IBs, their WMC capacity scores were not different to the IBs'. Although score estimations may be more reliable for Non-IB, IB subjects' scores may have been biased as a result of the amplitude decrease for the condition with set-size 4. These results justified the use of smaller set-sizes used in the main experiment for both experimental groups.

Supplementary Reference

Cowan, N. (2001). The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behavioural and brain sciences*, 24, 87-185. Doi: 10.1017/S0140525X01003922

Hannon, E. M., & Richards, A. (2010). Is inattentional blindness related to individual differences in visual working memory capacity or executive control functioning? *Perception*, 39, 309–319. Doi:10.1068/p6379

Jost, K., Bryck, R.L., Vogel, E.K., & Mayr, U., (2010). Are old adults just like low working wemory young adults? Filtering efficiency and age differences in visual working memory. *Cerebral Cortex,* 21, 1147-1154. Doi:10.1093/cercor/bhq185

Most, S. B., Simons, D. J., Scholl, B. J., Jimenez, R., Clifford, E., & Chabris, C. F. (2001). How not to be seen: The contribution of similarity and selective ignoring to sustained inattentional blindness. *Psychological Science*, 12, 9–17. Doi: 10.1111/1467-9280.00303

Owens, M., Koster, E.H.W., & Derakshan, N. (2011). Impaired filtering of irrelevant information in dysphoria: an ERP study. *Social cognitive and affective neuroscience*, 7 (7), 752-763. Doi: 10.1093/scan/nsr050

Papera, M., & Richards, A. (2016). Attentional Gain and Processing Capacity Limits Predict the Propensity to Neglect Unexpected Visual Stimuli. *Psychophysiology* (ahead of print).

Pashler, H. (1988). Familiarity and visual change detection. *Perception and Psychophysics*, 44, 369-378. Doi: 10.3758/BF03210419

Posner, M. I. (1969). Abstraction and the process of recognition. In G. H. Bower & J. T. Spence (Eds.), *The psychology of learning and motivation: Vol. 3. Advances in learning and motivation*. New York: Academic Press.

Richards, A., Hannon, E., & Derakshan, N. (2010). Predicting and manipulating the incidence of inattentional Blindness. *Psychological Research Psychologische Forschung*, 74, 513–523. Doi: 10.1007/s00426-009-0273-8

Richards, A., Hannon, E., & Vitkovitch, M. (2010). Distracted by distractors: Eye movements in a dynamic inattentional blindness task. *Consciousness and Cognition*, 21, 170–176. Doi: 10.1016/j.concog.2011.09.013

Scarborough, D. L. (1971) Memory for brief visual displays of symbols. *Cognitive Psychology*, 3(3), 408-429. Doi: http://dx.doi.org/10.1016/0010-0285(72)90015-1

Simons, D. J. (2003). *Surprising studies of visual awareness* (DVD). Champaign, IL: Viscog Productions. <http://www.viscog.com>.

Sperling, G. (1960). The information available in brief visual presentations. Psychological Monographs, 74 (11, Whole No. 498), 1-29.

Vogel, E. K., & Machizawa, M. (2004). Neural activity predicts individual differences in visual working memory capacity. *Nature*, 428, 748-751. Doi: 10.1038/nature02447

Vogel, E. K., McCollough, A. W., & Machizawa, M. G. (2005). Neural measures reveal individual differences in controlling access to working memory. *Nature*, 438, 500-503. Doi: 10.1038/nature04171