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The cubicle deconstructed: Simple visual enclosure improves perseverance

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ABSTRACT

The design of an office can affect productivity and work performance. Though social distraction (acoustic and visual distractions from other co-workers) certainly impacts performance, the effects of the spatial characteristics of the office environment per se are less known. We tested visual enclosure by simply adding a cubicle partition around a desk, and show in two studies that even this minor change improves perseverance, a central function underlying many job tasks. A third study suggests that this effect is likely caused by adjusting the allocation of mental effort depending on the environment, with larger spaces requiring a greater effort allocation. These findings suggest that environmental characteristics affect human performance by influencing the effort allocated to various tasks (effort allocation hypothesis) rather than by activating concepts related to enclosure (semantic priming). Overall, we suggest that visual enclosure in itself could be beneficial in tasks requiring perseverance.

1. Introduction

There is strong evidence to show that the physical characteristics of an office space can affect workers' behaviour, performance, and well-being (Ashkanasy, Ayoko, & Jehn, 2014; Davis, Leach, & Clegg, 2011; Lamb & Kwok, 2016). For example, Aries et al. (Aries, Veitch, & Newsham, 2010) found work performance was affected by the proximity of a window with a view. Bringslimark et al. (Bringslimark, Hartig, & Patil, 2009) reviewed the psychological benefits of plants in workspaces and found that, in general, indoor plants were associated with stress reduction and increased pain tolerance. Several studies have found effects of suboptimal thermal comfort (Geng, Ji, Lin, & Zhu, 2017; McCoy & Evans, 2005; Tan et al., 2018; Witterseh, Wyon, & Clausen, 2004), lighting (Nang et al., 2019; Veitch, 1990; Veitch & Galasiu, 2012; Zhu et al., 2017) and air quality (Allen et al., 2015; Wyon, 2004). Exposure to these environmental stressors reduce motivation and cognitive capacity for work (Hockey, 2013; Lamb & Kwok, 2016). All of these studies point to work performance being improved when employees rate their physical environment as comfortable.

Similarly, there have been many studies examining work performance in different office layouts. A common finding is that individual offices are superior to open-plan (Brennan, Chugh, & Kline, 2002; Haynes, Suckley, & Nunnington, 2017; Kim & de Dear, 2013). Cubicles around desks can alleviate some problems of large shared offices (Oldham & Fried, 1987), but not others (Brill, 1984). For example, Hongisto (Hongisto, Haapakangas, Varjo, Helenius, & Koskela, 2016) examined the effects of a refurbished office on employee satisfaction. While high partitions reduced some effects of noise, a reduction in visual distractions had to be considered in a trade-off with a loss of spaciousness. Being more isolated improves task performance (Davis et al., 2011) and enclosed offices are better than open plan offices for work that involves focus (Haynes et al., 2017; Vischer, 2008). The problems associated with open-plan offices are often associated with social distractions (Haapakangas, Hongisto, Varjo, & Lahtinen, 2018; Sundstrom & Sundstrom, 1986): acoustic noise from conversations and telephones are often cited (Pierrette, Parizet, Chevret, & Chatillon, 2015)) as well as feelings of crowding (Paulus & Nagar, 2015), lack of privacy (Bodin Danielsson & Bodin, 2009; Sundstrom & Sundstrom, 1986), territoriality (Vischer, 2008) and visual distractions caused by coworkers (Kim & de Dear, 2013; Oldham & Fried, 1987). These effects may be reduced in workers who are better at ignoring distractions (stimulus screening, Maher & von Hippel, 2005). Overall, these social distractions require mental effort to ignore, adding to the effort allocated to a worker's tasks (Davis et al., 2011; Hockey, 2013). However,

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few studies examine the effect of the spatial characteristics of the office environment in isolation (c.f. McCoy & Evans, 2005; Vischer, 2007), and these effects are modulated (and confounded) by the number of workers in a space, with lower levels of job satisfaction in more crowded offices (Otterbring, Pareigis, Wästlund, Makrygiannis, & Lindström, 2018; Paulus & Matthews, 1980).

Two key papers provide evidence towards the spatial characteristics of a room affecting workers, even when they are alone in the room. Both follow what we shall henceforth term the semantic priming hypothesis of environmental psychology. That is, that the visual environment semantically primes related concepts. Meyers-Levy and Zhu (2007) suggest that larger workspaces prime concepts of freedom, in comparison to smaller workspaces that prime concepts of confinement. They used testing rooms that were identical in every way apart from ceiling height (8m vs. 10m) and found that people make more "holistic" decisions in rooms with higher ceilings, becoming less specific in their responses. Similarly, Chan and Nokes-Malach (2016) showed an increase in divergent thinking and a corresponding decrease in convergent thinking when participants were seated in a large room in comparison to a small room. Their paper suggests that the effects shown are a consequence of automatic changes in semantic search patterns to match the physical environment. That is, search patterns are automatically constrained in a smaller (constrained) room, focusing attention to narrower searches.

An alternative possibility is that effort is being allocated to the physical environment and held in reserve (which we will term the effort allocation hypothesis). When a person can anticipate a particular activity, they allocate capacity to the activity in advance (Kahneman, 1973) and protect this allocated capacity from being used in the current task (Bosmans, Pieters, & Baumgartner, 2010). The amount of effort allocated to the future activity is determined by how much effort the participant assumes will be required, giving an estimated effort budget or working maximum (Brehm & Self, 1989).

The effort allocation hypothesis is supported by evidence showing that people automatically consider the amount of effort required to interact with the physical environment. Bhalla and Proffitt (1999) showed that outdoor slopes are perceived as steeper if the person estimating is carrying a heavy weight, and Proffitt (2006) demonstrated that many environmental perceptions are affected by a person's physiological potential. For example, distance information is affected by fatigue from a previous exercise task. Witt (2011) terms this action specific perception, where the perceived properties of the environment vary as a function of the anticipated effort costs. While calculations of environmental effort costs have been shown to be affected by current and previous states, there have been no studies examining whether the environment can influence task performance by changing the maximum amount of allocable effort available.

2. The present studies

In a series of three experiments, we examine whether a minor manipulation in the spatial environment affects the allocation of effort to a task. To avoid confounding effects of spatial or social crowding, we chose to focus on lone workers and used the exact same room for each participant in the study. We manipulated only one aspect of the room – whether the participant had a cubicle partition around their desk or not. The cubicle partition constrains the visual space around the participant. This allowed us to make specific predictions relating to the two theories outlined above.

In experiment 1, participants completed possible and impossible puzzles. A semantic priming hypothesis would predict that the addition of a cubicle partition would constrain the participant's space, priming fine-grained processing and concepts of confinement (Meyers-Levy & Zhu, 2007) and convergent thinking (Chan & Nokes-Malach, 2016), while reducing holistic, divergent thinking. This increase in convergent thinking would potentially reduce the number of attempts on the impossible puzzles, as the participants could fixate on one or a few strategies rather than considering a multitude of possible solutions. In comparison, without a cubicle partition, the participant's space would be much more open, priming holistic processing and increasing divergent thinking at the expense of convergent thinking, becoming less specific with their responses. This could lead to a greater number of attempts on the impossible puzzles in a similar way to idea generation in brainstorming (Rawlinson, 2017). The effort allocation hypothesis predicts the opposite effect. Following Gibson's (Ben-Zeev, 1981; Gibson, 1979; Greeno, 1994) ecological affordance approach, in an effort allocation model, perception would not extend beyond the person's potential for action. A cubicle partition around the participant's desk would constrain their potential for action to the desk only. Therefore this model would predict that the addition of a cubicle partition would reduce the effort allocated to the environment thus increasing the effort budget available for the experimental task, and, therefore, increasing the number of attempts on impossible puzzles. On the other hand, removing the cubicle partition would mean that the participant's potential for action would include the whole room thus increasing the effort allocated to the environment and reducing the effort budget for the experimental task, and, therefore, decreasing the number of attempts on impossible puzzles.

The semantic priming hypothesis would thus predict:

Hsem1: Constrained view reduces puzzle attempts

Whereas the effort allocation hypothesis would predict:

Heff1: Constrained view increases puzzle attempts

In experiment 2, participants completed a visual search change detection task with possible (change is present) and impossible (no change is present) searches. A semantic priming hypothesis would predict that the addition of a cubicle partition (reducing the participant's view of the room background) would semantically prime fine-grained, constrained search patterns (Chan & Nokes-Malach, 2016). That is, constraining the participant's view to the immediate area would prime foreground over background searches. Removing the cubicle partition should remove or reduce this bias by priming holistic processing, promoting background search. The effort allocation hypothesis, in comparison, would not predict any change in bias towards foreground or background searches, as both foreground and background searches can be considered as equal in effort, but again would predict that a cubicle would constrain the participant's potential for action to the desk only. This would mean that environmental effort is reduced, allowing greater effort allocation to the search task, increasing search time on impossible trials..

The semantic priming hypothesis would thus predict:

Hsem2: Constrained view promotes foreground search

Whereas the effort allocation hypothesis would predict:

Heff2: Constrained view increases search time on impossible trials

In experiment 3, participants were given an effortful task and asked to make a judgement on the fair payment for repeating the task. This is used as a measure of the perceived effort of the task. The semantic priming hypothesis would not predict any changes in perceived effort, as priming of fine-grained or holistic processing or strategies should not influence the effortful task. However, the effort allocation hypothesis would predict that a cubicle would reduce perceived effort. The constrained view would constrain the participant's potential for action to the desk only, giving a low environmental effort allocation. Therefore the total effort budget (environment + task) would be lower. When the cubicle partition is not in place, the participant's potential for action

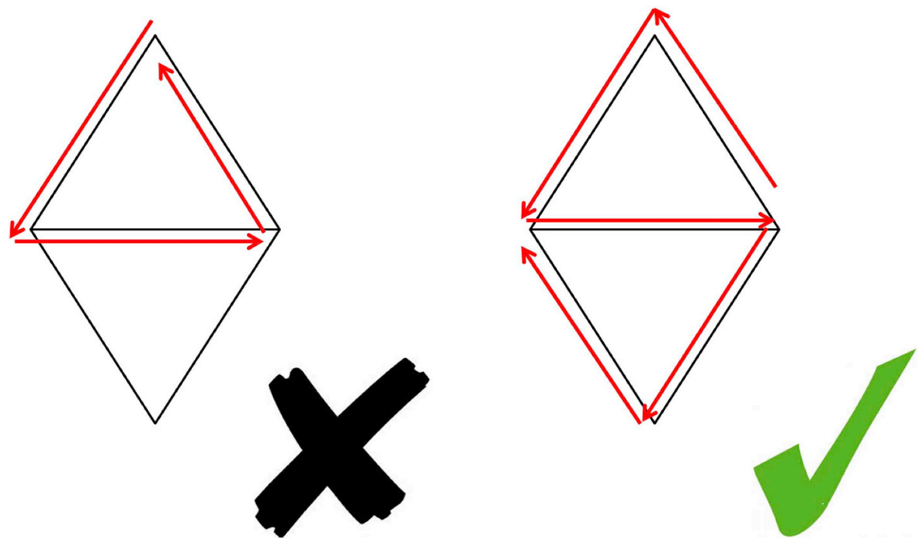

Fig. 1. Examples of incorrect (left) and correct (right) completion patterns for a simplified puzzle.

would extend to the entire room, meaning that the environmental effort allocation would be high, and the total effort budget would be higher.

The semantic priming hypothesis would thus predict:

Hsem3: Constrained view does not change perceived effort judgement

Whereas the effort allocation hypothesis would predict:

Heff3: Constrained view reduces perceived effort judgement

3. Experiment 1: frustration tolerance

We employ an established, widely used task to test perseverance (Feather, 1961; Frustration Tolerance Task - FTT). The FTT presents a participant with a set of possible and impossible puzzles. During the task, participants are asked to trace the lines of a diagram while following two rules: they are not allowed to lift their pencil from the paper and they are not allowed to trace over any line twice (see Fig. 1). Participants are allowed as many attempts at each diagram as they like; if they fail at a trial by not tracing over all of the lines they can take another copy of the diagram and start again. Participants are also allowed to choose to abandon a puzzle and move onto another if they cannot solve it. Performance in perseverance tasks can be affected by motivation (Battle, 1965; Feather, 1962), prior success (Feather, 1966), self-esteem (Mcfarlin, Baumeister, & Blascovich, 1984) and divergent thinking (Csikszentmihalyi, 2014). The environment has also shown to affect perseverance tasks, for example, having the ability to turn off an aversive background noise increases perseverance (Sherrod, Hage, Halpern, & Moore, 1977) as does being observed (Geen, 1981), possibly because of social facilitation. However, there are no previous studies examining the effect of changes in the visual environment on perseverance. Our manipulation of adding a cubicle partition suggests two possible outcomes: a semantic priming model would predict a reduction in perseverance through a reduction in divergent thinking. However, an effort allocation model would predict an increase in perseverance by reducing the effort budget allocated to the visible physical environment.

3.1. Participants

The study was approved by the local university Institutional Review Board. Sample size was estimated from a power analysis of Percival & Loeb (1980). Based on this we needed at least 25 participants per condition to achieve a power of 80% and alpha of 0.05.65 participants (29 females) aged between 18 and 30 were recruited for the study. All were fluent English speakers and had normal or corrected-to-normal vision. No neurological impairments or learning disabilities were reported. Participants gave their informed consent before taking part in the study and were compensated for their time.

3.2. Environment

Individual participants were tested, one at a time, in a large, air-conditioned windowless room. Eight tables lined the left and right walls of the room and the participant's testing desk was positioned directly in the centre of the room (see Fig. 2 for a plan view). Participants were randomly assigned to two conditions: Condition 1 sat at a desk surrounded on three sides by a wooden partition, extending 0.50 m from the surface of the desk (cubicle UP, Fig. 3a). This partition occluded approximately 255 degrees of their vision horizontally and a minimum of 90° vertically beyond the desk. Condition 2 sat at the same desk, where the wooden partition had been collapsed so that it extended only 0.13 m from the surface of the desk. These participants had a relatively unobstructed view of the room in front of them, with only 60 degrees of their vision occluded vertically (cubicle DOWN, Fig. 3b).

3.3. Procedure

Once seated at the desk, participants completed a questionnaire of demographic information. They were then required to estimate the distance from their table to the wall in front of them, to ensure they directed attention to their physical environment. Participants completed all questionnaires on a 13” laptop (Fujitsu Lifebook SH560) placed in the centre of the desk.

Before the frustration tolerance task, participants were asked to complete a 20 min unrelated decision making task (Christopoulos, Tobler, Bossaerts, Dolan, & Schultz, 2009; Holt & Laury, 2002). This was used to create a baseline level of workload and fatigue for each person. After the frustration tolerance task, participants completed two multidimensional subjective state questionnaires: the RAW NASA-TLX (Hart & Staveland, 1988) assessed workload using six subscales. The state fatigue scale (Earle, 2004) assessed mental fatigue (4 items), physical fatigue (2 items), sleep fatigue (4 items), boredom (2 items) and negative affect (3 items). Responses were made on 0–100 point scales.

For the frustration tolerance task, participants were presented with four stacks of puzzle papers in the sequence 1 (UNSOLVABLE) - > 2

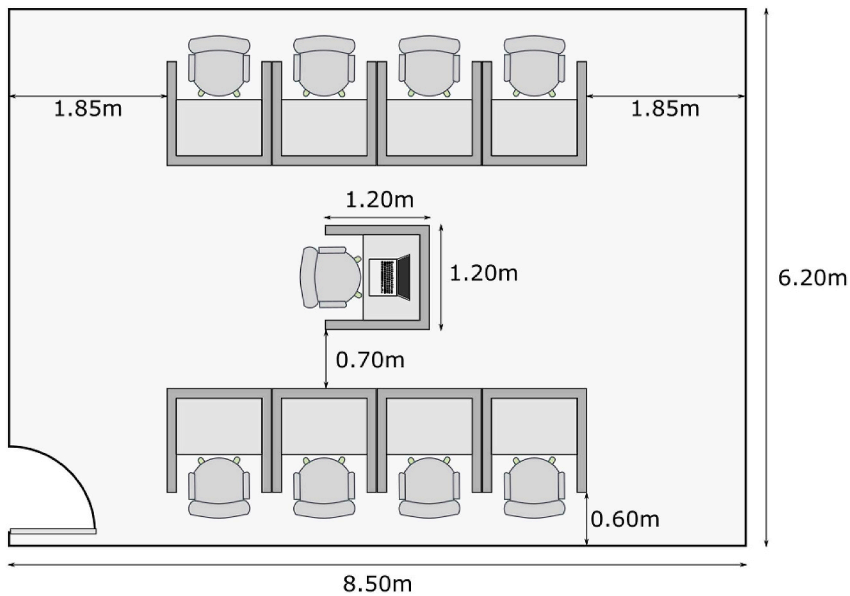

Fig. 2. Plan view of experimental room. The participant's desk was located in the centre of the room with the participant facing the wall.

(SOLVABLE) - > 3 (UNSOLVABLE) - > 4 (SOLVABLE) (Fig. 4). Participants were instructed to trace over all the lines in each puzzle, without repeating over the same line, and while making a continuous line from start to end. The participants were told that if they made a mistake they should try again on a fresh sheet of paper, and if they were unable to solve one puzzle, they should move on to the next. Participants had to attempt the puzzles in the order presented. Once a participant had moved on from a puzzle, they were not allowed to go back to it. The duration of the experiment was limited to 10 min, and participants were allowed to spend as much time on each puzzle as they liked, although they were told to attempt all four puzzles within the 10 min. The experimenter waited outside of the room until the end of the time limit to avoid possible confounding effects (crowding, fear of being watched, privacy, etc). Once the time limit was up, the experimenter collected the papers, noted the number of attempts at each puzzle, and asked the participant to complete the subjective state questionnaires.

3.4. Analysis

The frustration tolerance task results were analysed for number of attempts made at each puzzle. All analyses were conducted using the R language for statistical computing (R Team, 2013). As the score of number of attempts made per puzzle is effectively ordinal, we started with a non-parametric approach. To ensure that the results are robust to different statistical assumptions we conducted different statistical tests, briefly explained below.

Exact Wilcoxon Rank-Sum tests: The Exact Wilcoxon Rank Sum test (equivalent to the Mann-Whitney test) was used to compare the difference between the two conditions (cubicle UP vs cubicle DOWN). The function *wilcox.exact* from the package *exactRankTests* was used. This computes exact conditional p-values and quantiles using the Shift Algorithm (Streitberg & Roehmel, 1990) for tied samples (the ordinal nature of our data gave a high probability of ties). Exact p-values were computed and nonparametric confidence intervals for the difference of the location parameters (cubicle UP – cubicle DOWN) were computed. Confidence intervals were obtained using the algorithm described in Bauer (1972). The function *rFromWilcox* (in package *DSUR.noof*) was used to calculate effect sizes from the Wilcoxon test, using Cohen's (1988) criteria of 0.1 = small effect, 0.3 = medium effect, 0.5 = large effect.

Kolmogorov-Smirnov tests: The Kolmogorov-Smirnov (KS) two-sample test was used to compare the two conditions (cubicle UP vs cubicle DOWN) using a non-parametric test of the significance of the greatest difference in their cumulative distributions (Massey, 1951). Monte Carlo simulations were used to mitigate the uncertainty of asymptotic distributions of KS tests under the null hypothesis (Abadie,

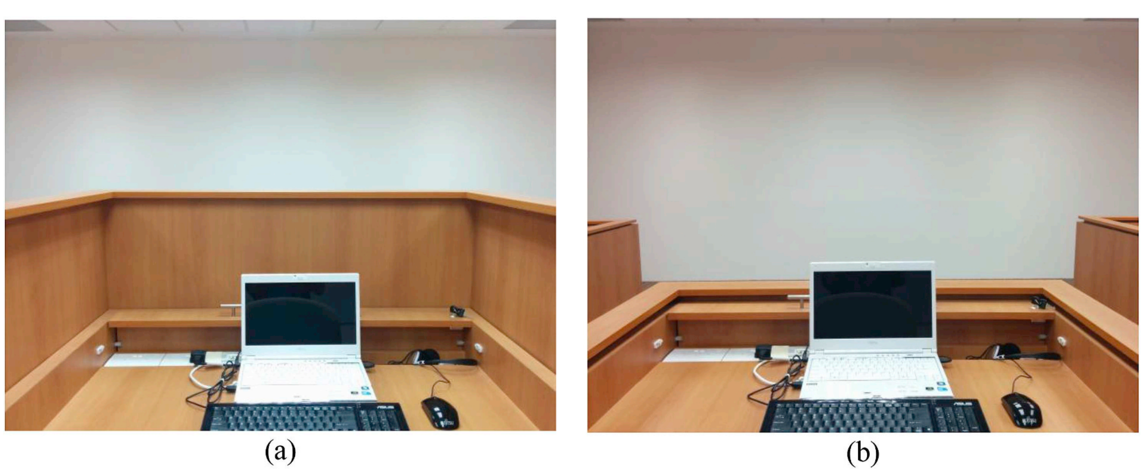

Fig. 3. Participant's view at desk with (a) cubicle partition UP, (b) cubicle partition DOWN.

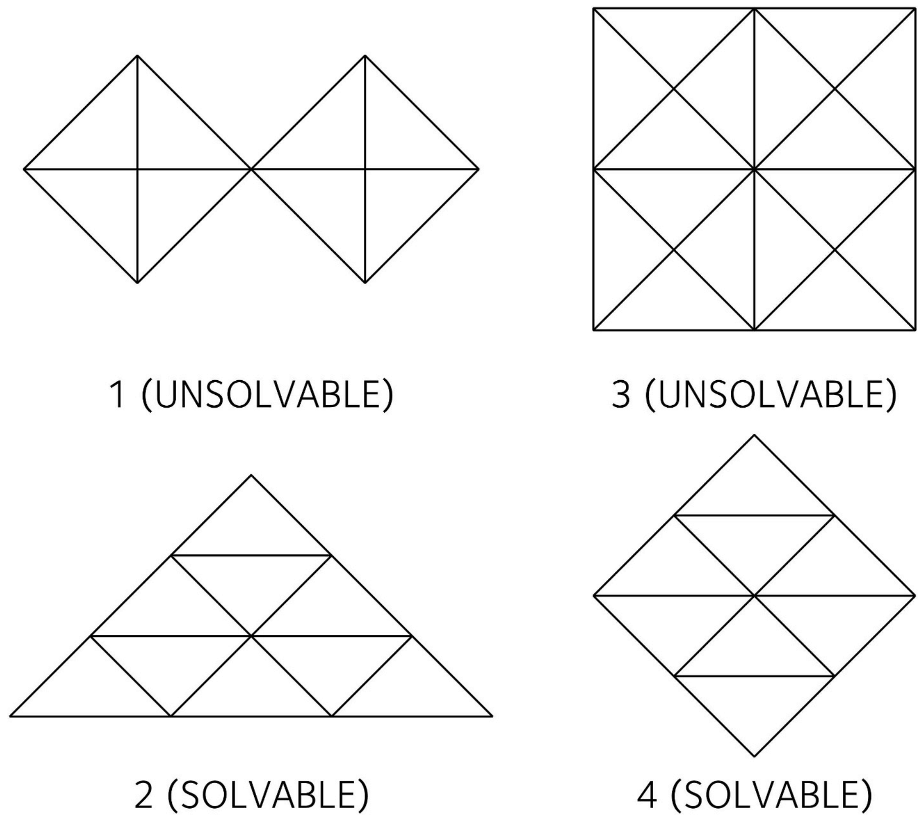

Fig. 4. The four puzzles used in the frustration tolerance task (Feather, 1961).

2002), which enabled the test to be conducted with data containing ties. The function *ks.boot* (from the *Matching* package) was used, with 100,000 simulations.

Kernel density estimates: Separate Kernel Density Estimates (KDEs) were used to generate probability densities for the two conditions (cubicle UP and cubicle DOWN) for each puzzle. Statistical tests for the KDEs were based on a null model of no difference between the distributions and a permutation test. The function *sm.density.compare* (from package *sm*) was used to compare the sum of squared differences between the pair of KDEs (cubicle UP and cubicle DOWN) to the difference computed from random permutations of the data (100,000 permutations).

Mixed effects model: The data from all four puzzles were combined into a mixed effect model analysis. The function *lmer* from the R package *lme 4* was used, with condition (cubicle UP vs cubicle DOWN), solvability (unsolvable vs solvable), and repetition (first or second of each puzzle type) as crossed fixed effects, with random intercepts for participants using Restricted Maximum Likelihood Estimation (Zuur, Ieno, & Smith, 2007). The R package *lmerTest* was used to estimate *p* values using Satterthwaite approximations. Finally, estimated marginal means and post-hoc contrasts for condition within each puzzle were generated using the *emmeans* package.

Subjective state questionnaires: Subjective data were reduced to their subscale mean values for RAW-TLX workload, mental fatigue, physical fatigue, sleep fatigue, boredom, and negative affect. Exact Wilcoxon Rank Sum tests were computed for the difference between the two conditions (cubicle UP vs cubicle DOWN, independent two sample WRS).

3.5. Results

Overall, nine participants (cubicle UP, 4 participants; cubicle DOWN, 5 participants) were excluded from analysis for failing to attempt the critical tasks (puzzle 1 and 3) correctly. Statistical analyses were performed on the data for fifty six participants, examining the number of attempts at each puzzle when the wooden partition was in place (cubicle UP, 28 participants) vs. when the partition was collapsed (cubicle DOWN, 28 participants).

Table 1 shows the summary statistics, Wilcoxon tests, KS tests and KDE tests for each puzzle. When the puzzle was possible (puzzles 2 and

Table 1
Summary of statistics for attempted puzzles in experiment 1.

Puzzle	Condition	M	Wilcoxon Rank Sum						KS		KDE	
			W	μ	95% CI		*p*	r	D	*p*	h	*p*
1 (impossible)	UP	7	230	−2.5	−5	0	.007*	-.36	0.39	.011*	1.48	.009*
	DOWN	4										
2 (possible)	UP	1	384	−0.5	−1	1	.890	-.02	0.07	.879	0.64	.876
	DOWN	1										
3 (impossible)	UP	6	199	−2.5	−5	−1	.001*	-.43	0.36	.022*	1.52	.003*
	DOWN	4										
4 (possible)	UP	3	150	−0.5	−2	1	.730	-.05	0.11	.892	1.78	.720
	DOWN	2										

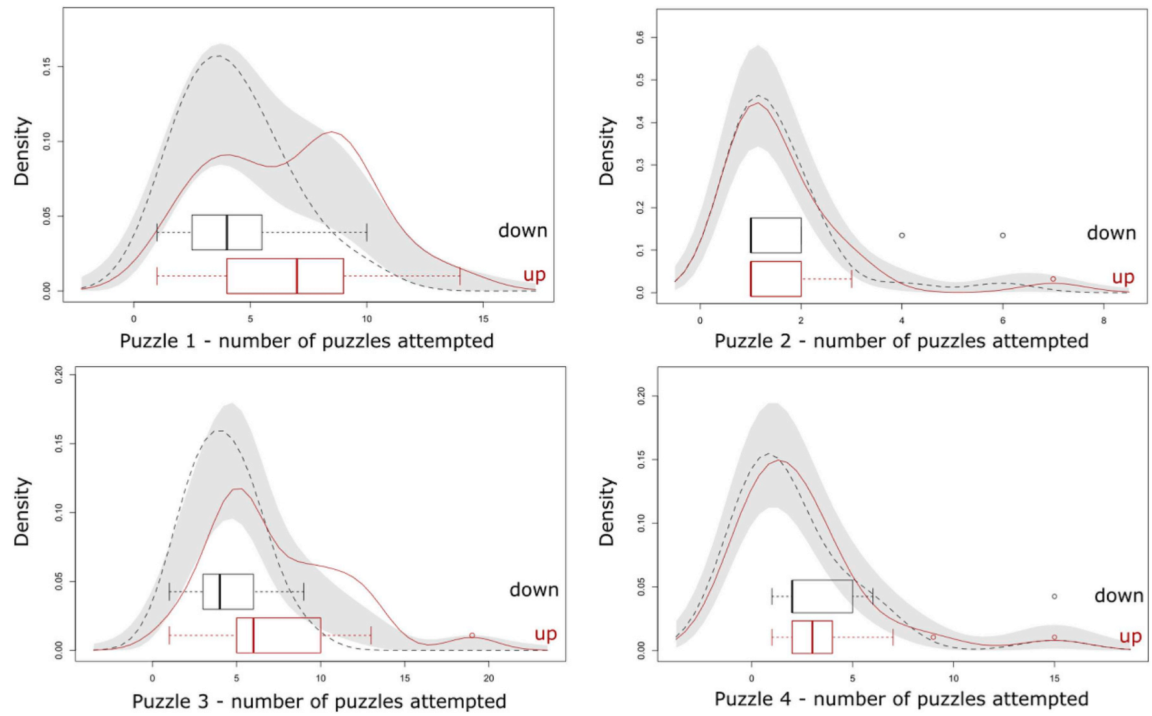

Fig. 5. Comparison of KDE (Kernel Density Estimate) probability density functions for Experiment 1. Solid and dashed lines represent KDE functions that approximate the cubicle partition UP and cubicle partition DOWN data respectively. Grey bands indicate one standard error either side of the null model of no difference between the KDEs.

4), there were no significant differences in number of attempts between the groups. However, significant effects were found for both of the impossible puzzles (1 and 3), with participants logging more attempts when the partition was up.

KDE plots for confirming the results for each puzzle are shown in Fig. 5. The figures include a band, indicating the null model of no difference between the paired KDEs. This was centred on the mean KDE and has a width of one standard error either side of the null model of no difference, thereby indicating regions of the distribution that are likely to be causing any significant effects (Bowman & Azzalini, 2012). For the impossible puzzles (1 and 3), the significant effects shown appear to be driven by a bimodal distribution in the responses from the participants in the cubicle UP condition.

Table 2shows the summary statistics and post-hoc t-tests for the mixed model. There were significant main effects of condition, $F(1,57.12) = 8.88$, $p = .004$, solvability, $F(1,56.22) = 62.66$, $p < .001$, and repetition, $F(1,109.04) = 14.06$, $p < .001$, and significant interaction effects of condition x solvability, $F(1,56.22) = 12.03$, $p = .001$, and solvability x repetition, $F(1,109.04) = 7.47$, $p = .007$. Based on this analysis, the model was separated by solvability into two models. For impossible puzzles, there was a significant effect of condition only, $F(1,54) = 15.42$, $p < .001$, where participants logged more attempts when the cubicle partition was up. For the possible puzzles, there was a significant effect of repetition only, ($F(1,115.32) = 18.40$, $p < .001$, where more attempts were made in the second possible puzzle.

Questionnaire data showed no significant effects between conditions (Table 3). This indicates that participants did not find the task more or less effortful in either condition.

3.6. Discussion

The results of Experiment 1 indicate that the inclusion of a cubicle partition around the participant's desk increases the number of attempts they are willing to make at (seemingly possible) difficult puzzles. There were no differences in the number of attempts before completion of the possible puzzles, which is expected given that they were completed within only a few tries, although there were differences between the first and second possible puzzle, suggesting fatigue or an order effect over the course of the session. These effects cannot be explained by social factors, as the participants were alone in the room while completing the task. The results of this experiment suggest that the view of the room affects the attentional resources allocated to the puzzle solving task, and is in line with the effort allocation hypothesis. The results of this experiment do not support a semantic priming hypothesis, which

Table 2
Summary of statistics for the lmer mixed model analysis in experiment 1.

Puzzle	Condition	Estimated Marginal Mean	Standard Error	95% CI		Post-hoc t-tests			
						t	df	*p*	d
1 (impossible)	UP	6.64	0.57	5.53	7.76	2.87	93.75	.005*	1.05
	DOWN	4.32	0.57	3.39	5.25				
2 (possible)	UP	1.64	0.43	0.53	2.76	0.12	117.08	.907	0.03
	DOWN	1.57	0.43	0.64	2.50				
3 (impossible)	UP	7.36	0.57	6.24	8.47	3.85	93.75	< .001*	1.40
	DOWN	4.25	0.57	3.32	5.18				
4 (possible)	UP	3.70	0.52	2.35	4.96	0.11	121.96	.915	0.04
	DOWN	3.62	0.55	2.44	4.84				

Table 3
Summary of statistics for questionnaires in experiment 1.

Subscale	Condition	Median	Wilcoxon Rank Sum					
			W	μ	95% CI		*p*	r
Raw TLX workload	UP	49.41	368.5	−1.33	−9.67	7.33	.705	-.05
	DOWN	51.25						
Mental fatigue	UP	21.63	393.0	0.25	−10.25	10.50	.990	-.002
	DOWN	24.75						
Physical fatigue	UP	13.75	347.5	−2.25	−13.00	3.50	.470	-.10
	DOWN	8.75						
Sleep fatigue	UP	21.50	393.5	0.13	−9.25	7.75	.984	-.003
	DOWN	21.63						
Boredom	UP	12.25	335	−2.25	−14.5	2.5	.353	-.12
	DOWN	6.75						
Negative affect	UP	18.00	350.5	−3.17	−14	5	.502	-.09
	DOWN	10.50						

would have predicted the opposite effect (a reduction in attempts when the partition was up). No effects were seen in the workload or fatigue questionnaires. This suggests that participants were not finding one condition more effortful, even though the participants in the cubicle UP condition were physically filling in more puzzle papers than those in the cubicle DOWN condition.

This study modified the original design from Feather (1961) by making the participant control the pacing of the task and not monitoring the participant throughout. These changes allowed us to limit confounding effects of being watched, but may have introduced other potential confounds: As the task was self-paced, participants may have not followed the instructions correctly, preferring to work out each puzzle in their heads rather than drawing on the paper. The fixed order of puzzle presentation could have also introduced an order effect. These confounds should not vary by condition, but could have introduced noise into our data.

4. Experiment 2: change detection

Experiment 1 used a well-established task in a novel context to examine whether the physical environment could affect perseverance on a task. While experiment 1 could therefore be seen as hypothesis-generating, experiment 2 was designed to be hypothesis-driven. Specifically, we aimed to test whether the addition of a cubicle partition around a desk would *increase* perseverance in a frustrating, seemingly possible task.

To account for the limitations in the previous study, for the second experiment we used a computer-based task that allowed better standardization of participant's behavioural options and strategies. The flicker change detection paradigm (Rensink, O'Regan, & Clark, 1997) is a commonly used method of measuring change blindness. In this, a series of images are presented which vary between an original and a modified image, and participants are required to identify how the image changes. A masking screen presented in between the two images acts as a simulation of the visual suppression caused by saccadic eye movements (Hollingworth, Schrock, & Henderson, 2001). Participants often take a significant amount of time to detect changes in these scenes, and this depends on the allocation of visual attention to the scene (Simons & Levin, 1997).

The semantic priming model would predict that participants would be semantically primed by their environment while engaging in the task. Therefore a participant with a constrained view of only the local area around them should be primed to direct their visual search to the foreground of images. A participant with an unconstrained view, able to see further away should not show a bias towards the foreground in visual search. In contrast to this, the effort allocation model would predict that there would be no difference in visual search style, but that the constrained view would increase perseverance by reducing the effort budget allocated to the visible physical environment.

4.1. Participants

The study was again approved by the local university Institutional Review Board. A new sample of 60 participants (29 female) aged between 18 and 34 were recruited for the study. All were fluent English speakers and had normal or corrected-to-normal vision. No neurological impairments or learning disabilities were reported. Participants gave their informed consent before taking part in the study and were compensated a variable amount for their time, based in part on their choices (see experiment 3).

4.2. Procedure

Participants again began the experiment by completing a demographics questionnaire, a distance estimation task, and the 20 min unrelated decision making task. After the change detection task, participants again completed two multidimensional subjective state questionnaires, the NASA-TLX and the state fatigue scale.

We presented a modified version of the flicker change detection paradigm (Rensink et al., 1997). Participants were presented with a series of fifteen paired photographs of natural scenes, where one image from each pair had been digitally altered to add, remove, or modify one small element of the scene (see Fig. 6). Stimuli were presented in the centre of the screen and were surrounded by a grey background. The average size of a change was 0.11% of the total area of the image (minimum 0.01%, maximum 0.29% of the image). Five of the image pairs contained changes in the foreground of the image, five pairs contained changes in the background of the image, and the remaining five pairs contained no change. Images were presented in a random order.

Written and oral instructions were given at the start of the experiment. Participants were instructed to attempt to find the change in every image pair. Once a change was identified, participants stopped the flicker by pressing the space bar, which overlaid a grid onto the image. Participants could then respond by typing the number of the grid square that contained the change. If they were unable to detect the change the participant could quit the pair and move to the next by responding with a zero. Each trial timed out at 120 s and participants were not informed that some trials may not contain changes. Participants completed one practice trial containing a larger change (0.93% of the image area) before starting the experiment. Trials began with a fixation cross in the centre of the screen, presented for 2000 ms.

Fig. 6. Change detection image pair for the practice trial of experiment 2.

After fixation, the paired images were displayed in a loop of 500 ms each, separated by a blank screen displayed for 90 ms.

4.3. Analysis

Responses were separated into impossible and possible trials. Impossible trials contained pairs of photos with no change; responses were coded as quit before the end of a trial (give up response) or to keep searching the images until the trial ended (timeout response). Possible trials consisted of trials where the change was in the background or the foreground of the image. In these trials, responses were coded as identifying the change correctly (correct response), quit before the end of the trial (give up response) and search until the end of the trial (timeout response). Subjective state data was treated in the same way as the previous task.

Response data. Proportions of the three response types across the two conditions (cubicle UP and cubicle DOWN) were visualized using mosaic plots with calculated adjusted residuals, and analysed using Logit Generalised Linear Mixed-Effects Models (using the function *glmer* from the R package *lmer 4*). For impossible trials, the proportion of timeout responses to give up responses (modelled as a binomial distribution) were examined with random intercepts and random slopes for image pair for the fixed effect of Condition. For possible trials, the proportion of correct responses (vs the combined proportion of give up and timeout responses) was first analysed, then the proportion of time out responses to give up responses was analysed separately.

Reaction time. Reaction times for correct responses in possible trials were analysed across the two conditions (cubicle UP and cubicle DOWN) for both foreground and background changes using mixed effect models (see experiment 1). Condition (cubicle UP vs cubicle DOWN) and change location (FOREGROUND vs BACKGROUND) were specified as crossed fixed effects with random intercepts for image pair and participants.

4.4. Results

No participants were excluded from the analysis. Statistical analyses were performed on 60 participants, examining performance when the cubicle was UP (30 participants) vs when the cubicle was DOWN (30 participants).

Impossible change detection trials. The glmer analysis showed a significant association between the cubicle partition position and whether participants would continue searching until the timeout, rather than giving up early, $z = 2.71$, $p = .007$. Based on the odds ratio, the odds of participants searching until the timeout were 2.54 times higher (95% CIs: 1.24, 5.39) if there was a cubicle partition around their desk (Fig. 7).

Possible change detection trials. The glmer analysis of correct responses showed no effect of condition, $z = 0.91$, $p = .365$, odds ratio = 1.13 (95% CIs: 0.80, 1.60), with participants identifying changes equally well regardless of whether they were surrounded by a cubicle partition. However, the analysis of timeout vs give up responses showed a significant effect of condition, $z = 2.47$, $p = .013$, where participants with a cubicle partition were more likely to search until the timeout if they could not correctly identify a change. The odds of participants searching until the timeout instead of giving up were 2.20 times higher (95% CIs: 1.14, 4.40) if there was a cubicle partition around their desk (Fig. 8).

Response times for correct responses in possible change detection trials showed no effect of condition, $F(1,57.65) = 0.06$, $p = .812$, $d = 0.05$, no effect of change location, $F(1,6.54) = 0.00$, $p = .964$, $d = 0.02$, and no interaction of condition x change location, $F(1,199.87) = 0.01$, $p = .927$, $d = 0.01$.

Questionnaire data. No significant effects were found in any of the questionnaire subscales (Table 4).

4.5. Discussion

The proportion of responses in both impossible and possible trials show, again, that when participants are unable to solve the change detection task (whether possible or impossible), they are more likely to persevere until a time limit if their desk is surrounded by a cubicle partition, supporting the effort allocation hypothesis.

The general pattern of increasing perseverance with a cubicle partition around the participant's desk does not, however, indicate that these people are more likely to correctly identify changes in the possible trials. There was no effect of the cubicle partition on the ability to identify changes between two images, therefore the cubicle partition does not improve visual search performance. Rather, it increases the likelihood of persevering. Again, there were no differences in the subjective workload or fatigue questionnaires, indicating that participants did not consider this increase in perseverance as more effortful. There was also no evidence to support the semantic priming hypothesis, which would predict that participants with a restricted view would be semantically primed to look for changes in the foreground of images; there was no effect of the location of the change in the image on reaction times in either of the two cubicle partition conditions.

5. Experiment 3: object sorting

To confirm the effort allocation hypothesis, immediately after the change detection task and questionnaire, participants moved on to experiment 3. We chose an object sorting task, where manual physical

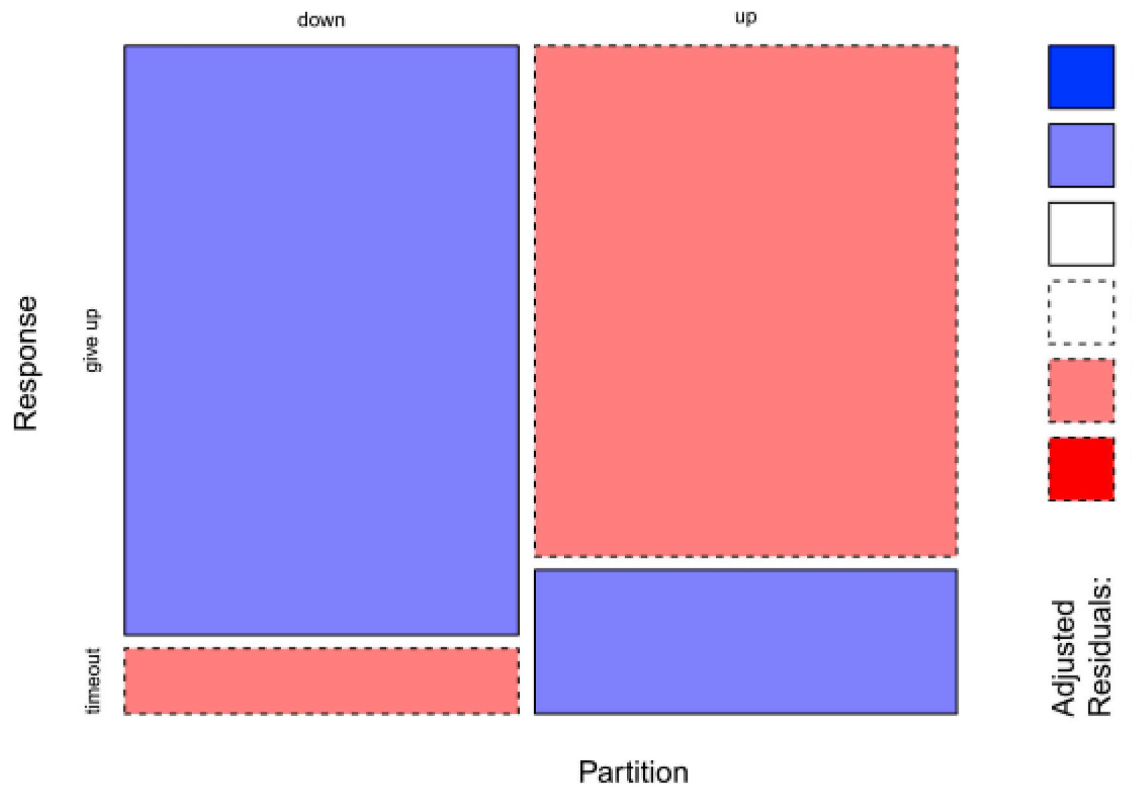

Fig. 7. Mosaic plot of proportion of responses in the impossible change detection trials for experiment 2.

effort was required as well as attention to detail to sort the items correctly. This object sorting task was used to provide a more substantial cognitive and physical load to the participants to elicit effort discounting. Effort discounting here refers to the reduction in a participant's subjective value (SV) of a reward as the expected effort to obtain that reward is increased (Kurzban, Duckworth, Kable, & Myers, 2013). In the effort allocation hypothesis, a reduction in the usable space in a room (by the addition of a cubicle partition around a desk)

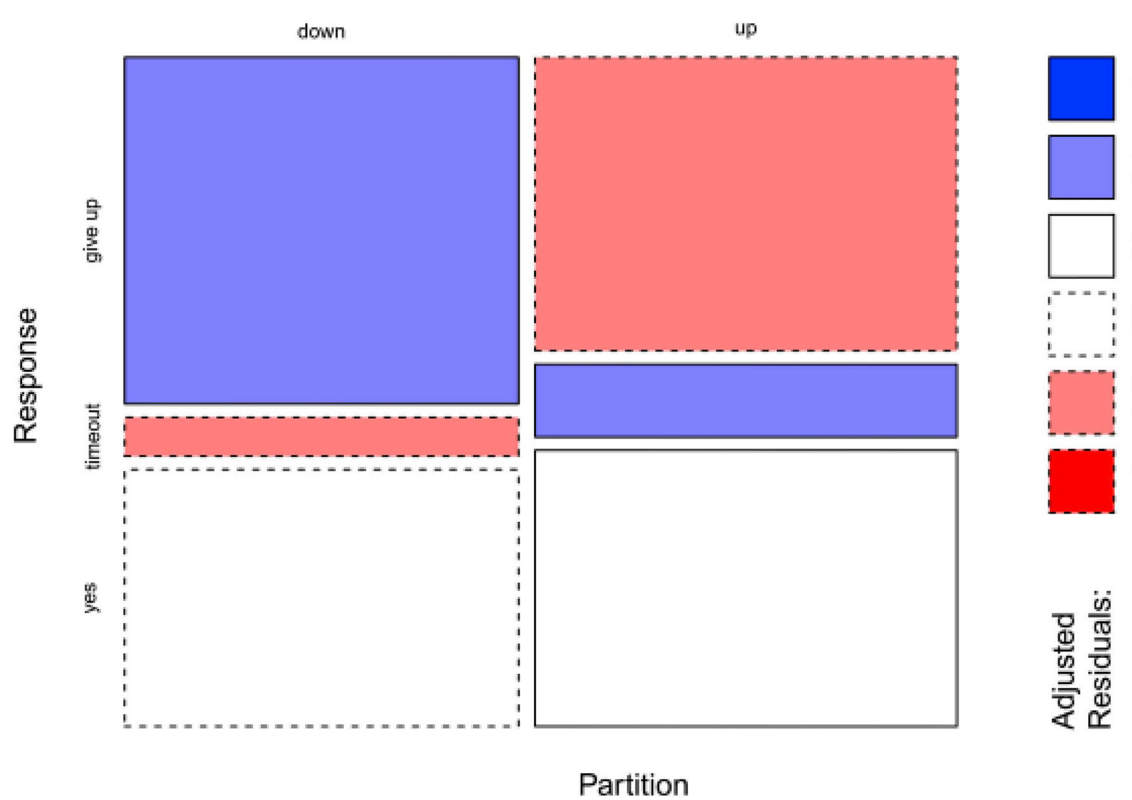

Fig. 8. Mosaic plot of proportion of responses in the possible change detection trials for experiment 2.

Table 4
Summary of statistics for questionnaires in experiment 2.

Subscale	Condition	Median	Wilcoxon Rank Sum					
			W	μ	95% CI		*p*	r
Raw TLX workload	UP	49.50	532.5	5.08	−3.17	13.83	.226	-.16
	DOWN	53.75						
Mental fatigue	UP	53.25	355.5	−9.63	−23.25	4.25	.165	-.18
	DOWN	43.88						
Physical fatigue	UP	32.75	432.5	−2.25	−18.00	14.50	.800	-.03
	DOWN	38.75						
Sleep fatigue	UP	53.13	336.5	−10.63	−26.25	3.00	.094	-.22
	DOWN	42.38						
Boredom	UP	35.00	350	−9.75	−28.00	3.50	.141	-.19
	DOWN	15.50						
Negative affect	UP	27.33	430.5	−1.33	−17.33	10.67	.778	-.04
	DOWN	27.67						

would reduce the expected effort budget of completing the object sorting task, thereby eliciting a greater SV of the reward. The semantic priming hypothesis would not predict any change in SV.

5.1. Procedure

Manual sorting task. Participants were given four bins, placed in front of them on the table. One bin contained a mix of long bolts, short bolts and nuts; the other three bins were empty. Participants were asked to sort the bolts and nuts into the three empty bins. They were only allowed to use one hand, and to pick one bolt or nut at a time. Time taken and errors (incorrect sorting of a long bolt into the short bolt bin etc.) were recorded. After the main task, participants again completed two multidimensional subjective state questionnaires, the NASA-TLX and the state fatigue questionnaire.

Effort discounting. After completion of the manual sorting task and questionnaires, we aimed to understand how participants value their effort. To that end we asked to choose between different combinations of effort and reward (see Table 5). Participants were presented with a series of choices between a no effort/low reward and a high effort/high reward option on paper and indicated their choice for each with a tick. The no effort/low reward option (on the left) always gave a reward of 1 Dollar, whereas the high effort option (on the right) required the participant to repeat the manual sorting task one, two, or three times and gave a reward from 1 to 15 dollars in fifty cent steps. Participants were told that one of their choices would be randomly selected at the end of the experimental session, and if they had selected the high effort option, they would be required to repeat the manual sorting task before receiving their payment.

Table 5
Example no effort/low reward vs. high effort/high reward option table for effort level 1, indicating the point at which a participant switched to the high effort option.

Would you rather …		
$1.00 and do nothing	OR	$1.00 and repeat the task once
$1.00 and do nothing	OR	$1.50 and repeat the task once
$1.00 and do nothing	OR	$2.00 and repeat the task once
$1.00 and do nothing	OR	$2.50 and repeat the task once
$1.00 and do nothing	OR	**$3.00 and repeat the task once**
$1.00 and do nothing	OR	**$3.50 and repeat the task once**
$1.00 and do nothing	OR	**$4.00 and repeat the task once**
$1.00 and do nothing	OR	**$4.50 and repeat the task once**
$1.00 and do nothing	OR	**$5.00 and repeat the task once**
$1.00 and do nothing	OR	**$5.50 and repeat the task once**
…		
$1.00 and do nothing	OR	**$15.00 and repeat the task once**

5.2. Analysis

Manual sorting task. Times to complete the sorting task were analysed across the two conditions (cubicle UP and cubicle DOWN) using the three tests (Exact Wilcoxon Rank-Sum, KS and KDE tests) used in the previous sections. Proportions of errors across the two conditions (cubicle UP and cubicle DOWN) were analysed using a loglinear model using the procedure in the previous section. Subjective state data was treated in the same way as the previous task.

Effort discounting task. For each participant, for each effort level (repeat the manual sorting task 1, 2, or 3 times), we estimated the indifference points in dollars ($) between repeating the task for $X or doing nothing for $1. This corresponded to the first point at which the participant changed from choosing the no effort option to the high effort option. The subjective value of each effort level was then calculated as (1/indifference point). Practically, higher indifference points suggest that the participant requests more money to repeat the task, assigning a lower subjective value (SV) to the task reward.

Outlier values were defined as those which were beyond 2 SD from the group mean. If a participant had one or more outlier values, their data was excluded from further analysis. A linear mixed effects model was used with crossed fixed effects of condition (cubicle UP vs cubicle DOWN) and effort level (1, 2, or 3 repetitions required), including participant as a random effect. Post-hoc contrasts were calculated using the function *pairwise* from the package *emmeans*. Cohen's d effect sizes were calculated for the post-hoc contrasts.

5.3. Results

Manual sorting task. No participants were excluded from analysis. Statistical analyses were performed on the data for 60 participants, examining the time to complete and number of errors made when the cubicle partition was in place (cubicle UP) vs when the partition was removed (cubicle DOWN).

There was no effect of condition on time to complete (WRS $p = .254$, KDE $p = .551$, KS $p = .547$) or number of errors, $\chi^2(5) = 7.01$, $p = .220$, indicating that participants in both conditions performed to the same level. There were also no effects in the subjective state questionnaires (Table 6).

Effort discounting. Eight participants were removed for having responses that were beyond 2 SD of the group means. Statistical analyses were performed on the data for 52 participants, examining the subjective value of the reward when repeating the manual sorting task 1, 2, or 3 times when the cubicle partition was in place (cubicle UP) vs when the partition was collapsed (cubicle DOWN). Following journal standards, we also report p values of data including outliers ($p_{with\_outliers}$).

Fig. 9 illustrates the estimated marginal mean averages for each

Table 6
Summary of statistics for questionnaires in experiment 3.

Subscale	Condition	Median	Wilcoxon Rank Sum					
			W	μ	95% CI		*p*	r
Raw TLX workload	UP	45.92	414	−2.75	−11.17	7.00	.600	-.07
	DOWN	44.25						
Mental fatigue	UP	22.38	362	−6.13	−15.50	3.00	.196	-.17
	DOWN	13.00						
Physical fatigue	UP	52.25	347.5	−11.75	−29.50	4.00	.131	-.19
	DOWN	40.00						
Sleep fatigue	UP	31.13	426.5	−1.63	−12.50	8.50	.733	-.04
	DOWN	28.63						
Boredom	UP	32.25	402.5	−3.75	−20.50	7.00	.488	-.09
	DOWN	20.50						
Negative affect	UP	14.00	363.5	−2.83	−9.33	2.00	.204	-.16
	DOWN	7.83						

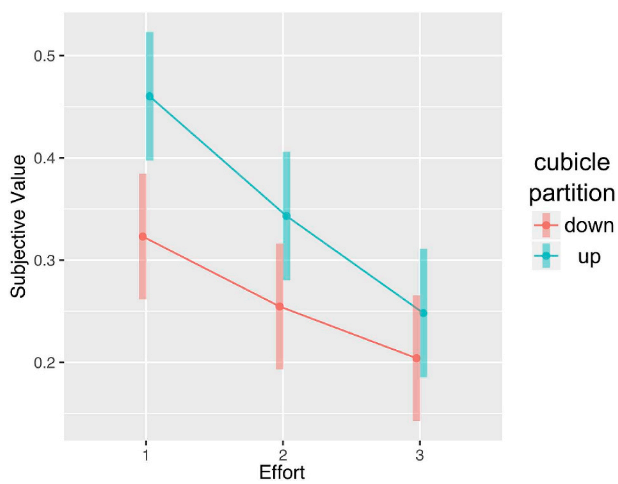

Fig. 9. Estimated Marginal Means of subjective value of the manual sorting task for three effort levels. Blue and red lines represent cubicle UP and cubicle DOWN conditions respectively. Bars indicate 95% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

level of effort. In general, participants gave higher subjective value to the task reward when the cubicle partition was up. There was a main effect of effort level, $F(2,100.93) = 66.08$, $p < .0001$ ($p_{with\_outliers} < .0001$), with participants giving lower subjective value ratings when prospective effort was increased suggesting that participants were indeed sensitive to higher levels of effort. There was a main effect of condition, $F(1,48.93) = 4.87$, $p = .032$ ($p_{with\_outliers} = 0.538$), and a significant interaction effect of effort x condition, $F(2,100.93) = 5.20$, $p = .007$ ($p_{with\_outliers} = 0.087$). Post-hoc pairwise contrasts were used to examine this interaction. The contrasts compared cubicle UP vs cubicle DOWN at each level of effort. At effort level 1, there was a significant effect, $t(65.80) = -3.11$, $p = .003$, $d = -1.87$, showing that when the cubicle was UP the participants attributed a higher subjective value to the reward and required less money to repeat the task again. At effort level 2, there was also a significant effect, $t(65.80) = -2.01$, $p = .049$, $d = -1.20$. However, the third effort level did not show significant effects, $t(65.80) = -1.00$, $p = .320$, $d = -0.60$), this could indicate a ceiling effect very often observed in high effort values (Halamish, Liberman, Higgins, & Idson, 2008; Reed & Martens, 2011; Yi & Landes, 2012).

5.4. Discussion

While all participants performed equally in the manual sorting task, they did not attribute the same degree of effort to the task. This can be seen in the effort discounting, where participants who had a cubicle partition around their desk attributed a higher subjective value to the task. This means they required a lower amount of monetary compensation to repeat the task once than the participants who did not have a cubicle partition. However, this effect went away at the highest effort level. This could be a ceiling effect caused by the maximum reward offered in the experiment (15 dollars). The effect seen in the effort discounting task did not appear in either the NASA TLX assessing workload, or the state fatigue scale.

6. General conclusions

Over three experiments, we have shown a consistent pattern of results where a constrained view (the addition of a cubicle partition around a desk) increases perseverance at a task. The effort discounting task in experiment 3 suggests that this may be related to changing the perceived effort cost of doing the task. This is consistent with the hypothesis that the working environment requires allocation of mental effort.

The change in perseverance seen in experiments 1 and 2 does not appear to be related to a change in task performance. In experiment 1, possible puzzles were presented alongside the impossible puzzles. There was no change in the number of attempts before completing these puzzles. In experiment 2, possible change detection tasks were presented. While the addition of a cubicle partition reduced the likelihood of participants quitting the task early, the number of correctly identified changes, and the time to correctly identify changes were not affected.

The effects seen in the effort discounting task suggest that having a cubicle partition around the desk reduces the perceived effort required to complete a task. This effect was not detected in any of the questionnaire responses, where participants did not differentiate the levels of workload, fatigue, boredom or negative affect across the conditions. Benoit et al. (2019) suggest that subjective fatigue (as measured by questionnaires) develops independently of what they term “cognitive task avoidance” (as measured by effort discounting tasks). Using a model of “anticipatory regulation”, they suggest that a reduction in subjective value (increase in cognitive task avoidance as measured by effort discounting tasks) is a protective mechanism to anticipate future need of resources. This ties in with Witt's (Witt, 2011; Witt, Linkenauger, & Wickens, 2016) action specific perception and Proffitt's (Bhalla & Proffitt, 1999; Proffitt, 2006) embodied perception studies and aligns with the effort allocation hypothesis advocated here.

Our results can be explained both by resource models of attention (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Benoit et al., 2019; Vohs et al., 2008; Wang, Novemsky, Dhar, & Baumeister, 2010) or by motivational models (Earle, Hockey, Earle, & Clough, 2015; Hockey, 2013; Kurzban et al., 2013). The opportunity cost model of executive function (Kurzban et al., 2013) assumes that the utility of a current goal (similar to SV) is compared to alternative goals in the environment. If the opportunity cost of the current goal is too high, the participant may switch to an alternative with a lower cost. This model does not make any specific predictions about the influence of environmental factors on effort. In comparison, the motivational control model (Hockey, 2013) considers environmental factors as stressors that can disrupt goal maintenance. In this model, stressors are overcome by an increase in goal-directed effort, which in turn will increase feelings of fatigue. Our findings suggest that certain environmental factors could be modelled as parallel tasks that require an effort budget (rather than stressors that influence the current task per se). This would reconcile our findings with the opportunity cost model, where we can assume that a more accessible environment increases the perceived opportunity cost of the primary task by giving a greater range of non-target tasks that could be selected.

6.1. Alternative priming pathways and effort allocation

In this paper, we examined effects of visual enclosure on aspects of human cognition in light of a priming hypothesis (fine-grained vs. holistic thinking modes) compared to the effort allocation hypothesis (environment with low vs. high effort demands). Despite that our results can be interpreted as favouring the effort allocation hypothesis, it might very well be possible that other priming modes are active and actually contributing to the estimation of the effort allocated; indeed this possibility would need to be thoroughly tested in future research. For example, mindset priming could occur, where the addition of a cubicle partition could increase feelings of isolation or claustrophobia. Indeed, Cesario et al. (Cesario, Plaks, Hagiwara, Navarrete, & Higgins, 2010) show that priming effects rely heavily on the testing environment, where a cubicle around the participant reduces their behavioural response options in a fight or flight scenario. Lee (Lee & Schnall, 2014) used priming to show that a low sense of power will increase the amount of perceived effort to lift a weight. Anderson and Berdahl (2002) similarly found that priming with a higher sense of power could elicit more positive emotions. In the context of our experiments, the inclusion of a cubicle partition could reduce feelings of agency or control, thereby increasing perseveration (the inability to appropriately switch to a new strategy). While our second experiment does not distinguish between perseveration and perseverance, our first experiment would assume that perseverative individuals would not make more puzzle attempts as they would be unable to generate other possible solutions to the puzzles. Further study is needed to understand the exact mechanisms, for example through manipulating control or priming with a different modality that would give different predictions for the effort allocation model; or by parametrically testing the effects of changing other architectural parameters (e.g. room size, ceiling height) using virtual reality applications (Roberts et al., 2019). It is also worth bearing in mind that priming effects are very context specific (Tulving & Schacter, 1990) and can be difficult to replicate (Shanks et al., 2013).

6.2. Practical implications

Human activities are almost always place-specific and rooted in collective social practices (Heft, 2018); cubicles are typically associated with office-related work that is associated with specific actions and outcomes. The present results indicate that tasks that require sustained perseverance could benefit from being performed in such enclosed spaces. This is in contrast to preference studies, which often identify openness as an important feature (e.g. Ergan, Shi, & Yu, 2018) and suggest that “lean” visually simple environments could be psychologically impoverished in comparison to “enriched” complex environments (Bringslimark, Hartig, & Patil, 2007; Knight & Haslam, 2010), but in agreement with studies that show improved performance in standard office environments in comparison to more visually complex environments (Moskaliuk, Burmeister, Landkammer, Renner, & Cress, 2017). While perseverance may be improved by enclosure, previous papers have found that open-plan offices score higher for other aspects which may be desirable such as social factors (Bodin Danielsson & Bodin, 2009). Open plan offices with window views can increase visual glare, but increased window views tend to increase occupant tolerance of glare and increase satisfaction with lighting (Kong, Utzinger, Freihoefer, & Steege, 2018). Our results are independent of confounding factors such as visual privacy and acoustic noise, and suggest that even in single room offices (cell offices), it may be preferable to include a cubicle partition around a worker's desk. However, this has to be considered in the context of worker-work environment fit, as workers can differ in their needs and work styles (Vischer, 2007).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2019.04.002.

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