Objects but not concepts modulate the size of the attended region

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Abstract

Here we investigated the types of stimuli that modulate the size of the attentional spotlight. In particular, it has been previously shown that conceptual cues that either directly refer to or are semantically related to particular spatial locations can shift attention to that location (known as ‘*conceptual cueing*’). For example, reading the word *sun* or *joy* can shift attention upward whereas the word *boot* or *hostile* can shift attention downward. Here, therefore, we tested whether words could modulate the size of the attended area. Across five experiments, we found that words that either directly referred to, or were abstractly associated with, particular sizes (small versus large) did *not* change the size of the attentional spotlight, whereas the presence of differently-sized stimuli did, as evidenced by faster responses to targets when the spotlight is small compared with when it is large. This suggests that physical but not conceptual inducers can modulate the size of the attentional spotlight. This highlights an important difference between the regulation of spotlight size and shifts of attention, supporting the notion that they are subserved by distinct mechanisms.

Keywords: visual attention; spatial attention; visual span; attentional spotlight; conceptual cueing; zoom-lens.

Visual attention is a core visual-cognitive process that can improve both the objective perceptual performance as well as subjective resolution of perceptual content (Carrasco, Loula, & Ho, 2006; Gobell & Carrasco, 2005). Traditionally, the operation of visual attention has been conceptualised as akin to a spotlight, where objects and regions that fall within the spotlight's beam are attended and receive privileged processing (Posner, 1980; Posner & Cohen, 1984). There are two major ways in which this attentional spotlight can be regulated: its location in space can be moved, and the size of the attentional spotlight can be modulated, also sometimes historically conceptualised as the function of a zoom-lens (e.g., Eriksen & St. James, 1986). The purpose of the present study was to assess what types of stimuli are effective in regulating the size of the attentional spotlight. This is an important question in its own right because spotlight size is such a fundamental aspect of visual attention, and therefore understanding what factors do and do not influence its operation is crucial to understanding visual-cognitive functioning. Furthermore, it also speaks to broader theoretical question of whether spotlight size changes and shifts of attention share common or instead rely on distinct underlying mechanisms. Here we addressed this question by assessing whether both of these processes are responsive to conceptual manipulations. If they both are, then it is consistent (but not conclusive) with them having common mechanisms. In contrast, if concept words trigger shifts of attention but not modulations in spotlight size, then this highlights an important dissociation in the mechanisms underlying these two fundamental attentional processes.

Historically, it has been conceptualised that there are two main ways in shifts of the attentional spotlight can be triggered. The first way is that attention can be automatically or reflexively 'captured' to a location by a salient stimulus. This is known as exogenous orienting, or transient attention. Exogenous shifts of attention are usually

measured via presentation of a peripheral cue, which rapidly captures participants' attention to its location, even when it is not predictive of the subsequent target's location and thus unhelpful to the participants' task. In contrast, the second way is that the attentional spotlight can also be voluntarily moved in space in order to exploit an informative or goal-relevant location. This is called endogenous orienting, or sustained attention. Unlike exogenous cueing, endogenous shifts of attention are typically gauged via the presentation of central cue that is symbolic, informative, and predictive (Giordano, McElree, & Carrasco, 2009; Hein, Rolke, & Ulrich, 2006; Muller & Rabbitt, 1989; Nakayama & Mackeben, 1989).

Challenging a simple and clear dichotomy between exogenous and endogenous cueing, more recently it has also been shown that the attentional spotlight can also be shifted by conceptual cues (Chasteen, Burdzy, & Pratt, 2010; Estes, Verges, & Adelman, 2015; Estes, Verges, & Barsalou, 2008; Goodhew, McGaw, & Kidd, 2014; Gozli, Chasteen, & Pratt, 2013; Setic & Domijan, 2007). For example, after presentation of a central word such as *sun*, attention is oriented to upward locations, whereas after presentation of a central word such as *ground*, attention is oriented to downward locations. Such conceptual cueing effects occur for concrete words that refer to objects whose prototypical locations are upwards or downwards, but also in response to abstract words whose valence is positive or negative, such as up for *joy* and down for *bitter*. Words referring to time can also affect attention (e.g., *yesterday* = left, *tomorrow* = right) (Weger & Pratt, 2008). Such conceptual cueing effects have been observed on a variety of different dependent measures, including behavioural efficiency of target detection and target identification, and even saccadic latency and trajectory (Dudschig, Souman, Lachmair, de la Vega, & Kaup, 2013; Gozli, Chow, Chasteen, & Pratt, 2013). Conceptual cueing bears resemblance to endogenous cueing, given the

central and meaningful cue presentation, however, it is observed even though the words themselves (at least in the experimental context) are not predictive of the location of subsequent targets. In this sense, therefore, conceptual cues represent another example of a violation of, and thus a growing consensus of dissatisfaction with the theoretical framework of a strict exogenous/endogenous dichotomy (Awh, Belopolsky, & Theeuwes, 2012). Other meaningful real-world stimuli, such as eye-gaze, also orient attention when faces displaying particular directions of gaze are presented centrally, but this is so even when the direction of gaze is not predictive of the location of the subsequent target, thus further breaking down the traditional definitions of cue types (e.g., Frischen, Bayliss, & Tipper, 2007). Altogether then, attention can be oriented by a variety of cues, and while historically the terms *exogenous* and *endogenous* have been used, they appear to have limited utility when it comes to more meaningful cues, and thus we will not use the terminology in our experiments.

While there exists an extensive literature on the type of stimuli that elicit shifts of attention, the ways in which the *size* of the attentional spotlight can be modulated, in the absence of a shift in its central location are less well understood. It has been demonstrated that attentional spotlight size can be exogenously modulated, in that outline shapes that are either big or small impair or facilitate responses to target onset when varied randomly from trial to trial (Benso, Turatto, & Gastone, 1998; Castiello & Umiltà, 1990). Furthermore, rather than varying the size of the attentional spotlight from trial to trial, a more sustained change in spotlight size can occur. This is done when the same spotlight size is consistently induced across a block (e.g., all large stimuli shown to induce a large spotlight size) (Goodhew, Shen, & Edwards, in press; LaBerge, 1983). Moreover, stimuli at uncued (Posner-style) locations are responded to with higher accuracy when presented inside the same texture (i.e., the same pre-

attentively grouped unit) as the cued location, compared with stimuli presented outside the texture, despite being a constant physical distance away. This suggests that visual attention spreads texture-wise across the visual field (Feldmann-Wustefeld & Schubo, 2013). What remains untested, however, is whether the size of the attentional spotlight can be modulated in response to conceptual cues (or hereafter inducers when we refer to words changing the size of the spotlight rather than changing the location of the spotlight in space). This was the purpose of the present study. The theoretical question being addressed, therefore, is whether shifts of attention and changes in the size of the attentional spotlight are elicited by common factors, and therefore, by extension, whether they might be mediated by common underlying mechanisms. If shifts of attention and regulations of spotlight sizes are both elicited by concept words, then it is consistent with the notion that they might be mediated by common underlying mechanisms. In contrast, if spotlight size is not affected by concept words, then it supports the notion that they have different underlying mechanisms.

EXPERIMENT 1

The purpose of Experiment 1 was to establish whether conceptual cues could modulate the size of the attentional spotlight, in addition to physical cues, which have been previously demonstrated to be effective. To this end, we employed conceptual cues (i.e., words) that referred to different attentional spotlight sizes: *big* and *large* versus *small* and *little*. We measured participants' target detection speed in response to target onset after these cues. We compared performance in this condition against performance in a standard physical inducer cue condition, in which either a small or large outline circle appeared prior to target onset. This manipulation has been shown to modulate the size of the attentional spotlight, such that it facilitates responses to targets inside the small circle relative to the larger circle (Benso et al., 1998). If conceptual cues can also

modulate the size of the attentional spotlight, then responses to the target should be more efficient after the cue words '*small*' or '*little*' compared to responses after the cue words '*big*' or '*large*'.

Method

Participants

Twenty-four participants were recruited via an Australian National University website who participated in exchange for either course credit or pay. Of these, 19 were female and 5 were male. Their mean age was 20.6 years ($SD = 2.6$). Four reported being left-handed and the rest right-handed. All participants in all experiments provided written informed consent prior to participation.

Apparatus

Stimuli were created in the Psychophysics Toolbox (Brainard, 1997) in Matlab, and presented on a CRT monitor running at refresh rate of 75Hz. The background screen was set to grey.

Stimuli

Physical inducer stimuli were either small (subtending 2° of visual angle in diameter) or large (subtending 20°) unfilled circles. The target was a filled grey circle which subtended 0.40° (and thus fitted within the smallest inducer) and always appeared in the centre of the screen. All of these stimuli were 30% darker grey than the background. Words were presented in black size 18 Courier New font, and appeared above the target location. In order to facilitate the possibility of the words modulating spotlight size, in addition to the word cue, participants were provided with reference frames, which corresponded to both the 2° and 20° unfilled circles simultaneously with the word cues.

Procedure

On each trial, a small white fixation dot was presented in the centre of the screen for 253ms, until an inducer (either small *or* large) was presented for 200ms (see Figure 1). When the inducer was a word, reference frames (i.e., both small *and* large inducers) were also presented. Then the target was presented in addition to the inducer for until either a response was made. Participants' task was to press the spacebar as soon as they detected the appearance of the target. The target was absent on 15% of trials (catch-trials). Inducer type (physical versus word cue) was blocked, and order of block completion was counterbalanced across participants. Whether a given trial had a small or large inducer was randomly determined and equiprobable. There were 500 trials per block (where one block = all of the conceptual or physical inducer trials); with rest breaks provided within blocks every 125 trials. This means that there were 1000 total trials in the experiment. At the beginning of each block, participants completed a practice block which consisted of 12 trials which provided participants with feedback on the accuracy of each response or nonresponse ('GOOD!', 'Too Slow!', 'Oops – should not have responded!' appeared in green or red on the screen). Participants needed to score at least 75% correct on this (repeated as required) before progressing to the experiment.

Figure 1A. An illustration (not to scale) of the general trial structure used throughout the experiments in this study. In the first display, a fixation-only stimulus is shown, in the second, the fixation plus inducer shown for a given SOA (ranging between 200 and

1200ms, depending on experiment). In some cases, this display also included the presence of reference frames (see Figure 1B). In the third display, the target appears. The inducer (and reference frames, if applicable) also stayed on the screen during this third display.

Figure 1B. An illustration (not to scale) of the different types of spotlight size induction methods in the different conditions. The upper panels illustrate manipulations of large spotlight size and the lower panels illustrate manipulations of small spotlight sizes. This illustration shows the cues with the target presented simultaneously, but note that the onset of the cues actually preceded the target array onset (see Figure 1A). When presented, the target (grey circle) was always presented in the centre of the screen. Participants' task was to detect the onset of the target. In the physical inducer condition, the inducer was always centred on the target, and in the conceptual condition, the word was always presented just above the target. When reference frames were presented (as they were here in Experiment 1, but not in Experiment 2) in the conceptual condition, they replicated both the small and large physical inducers simultaneously, and thus do not provide a physical a manipulation of a particular spotlight size, but instead help to

provide a physical reference system for size. While this reference frame means that there was some spatial contiguity between the word and the focal inducer, the different contrast (black word versus grey inducer) and different form (curved inducer versus angular letters) helped ensure their discriminability.

Results & Discussion

Data from one participant was excluded because they completed the physical inducer block twice and did not complete the word inducer block. Data from the remaining 23 participants were analysed. We first checked participants' average accuracy on the catch trials, where the target was not presented and thus an 'accurate' response constitutes withholding a response. Two participants were excluded for very low accuracy on the catch trials ($\leq 5\%$ accuracy for the word cue condition). Accuracy for the remaining 21 participants was high (92% for both the physical inducers and word cue conditions).

Figure 2 (the left hand panel has pattern for Experiment 1) shows that inducer words appeared to impact reaction time for the physical inducers, but not the word cue inducers. To confirm this pattern was reliable, reaction times were submitted to a 2 (inducer type) $\times$ 2 (size) repeated-measures ANOVA. This revealed no main effect of inducer type ($F < 1$), but a main effect of size, $F(1, 20) = 57.27, p < .001, \eta_p^2 = .741$, and a significant interaction between inducer type and inducer size, $F(1, 20) = 21.95, p < .001, \eta_p^2 = .516$. Repeated measures t -tests with the Bonferroni correction applied (critical alpha = .025) revealed that this interaction reflected the fact that inducer size strongly impacted reaction time for the physical inducers, such that responses were quicker with the small (293 ms) relative to the large (317 ms) inducers ($p < .001$). In contrast, size had no reliable impact on reaction time when it came to word cues ($p =$

.730). In other words, attentional spotlight size appeared to be modulated by physical, but not conceptual cues.

Figure 2. Reaction time to detect the onset of the target as a function of inducer type (physical stimulus versus word cue), and the size of the inducer (whether it was physically small or large, or whether the semantics of the word cue referred to small or large) in Experiments 1 and 2. Error bars represent standard errors of the mean corrected for within-subjects designs (Cousineau, 2005).

EXPERIMENT 2

The purpose of Experiment 2 was to check that the absence of spotlight size modulation in response to word cues was not a product the specific methodology employed. Specifically, in the previous experiment, we provided participants with reference frames to encourage the adoption of small and large attentional spotlights in response to the conceptual cues that referred to small and large (and little and big). However, this may have had the unintended consequence of actually compelling a small attentional spotlight throughout the word cue condition, and thus causing the absence

of size modulation, if, for example, the small reference frame, by virtue of being closer the centre of the screen was more ‘dominant’ induction, even though both small and large inducers were presented simultaneously to provide reference frames. To test this possibility, in this experiment, the word cues were presented alone without reference frames.

Method

Participants

Twenty-four participants were recruited from the same means as Experiment 1. Of these, 16 were female and 8 were male. Their mean age was 20.0 years ($SD = 2.8$). Three reported being left-handed and the rest right-handed.

Apparatus & Procedure.

Details of the apparatus and procedure were identical to Experiment 1, except that the reference frames were removed from the word cue condition (see Figure 1).

Results & Discussion

Participants tended to comply with the instruction to withhold responses on the catch trials: their average accuracy on these trials was 85% and 87% for the physical inducer and word cue conditions respectively. As can be seen in Figure 2, the pattern of results was qualitatively the same as in Experiment 1: reaction times to detect the onset of the target appeared facilitated with the small physical inducer relative to the large physical inducer, whereas the size referred to by the word cues appeared to have no impact on response efficiency. To confirm the reliability of this pattern, reaction times were submitted to a 2 (inducer type) $\times$ 2 (size) repeated-measures ANOVA, which demonstrated no main effect of inducer type ($F < 1$), a main effect of size, $F(1, 22) = 20.31, p < .001, \eta_p^2 = .480$, and a significant interaction between inducer type and size, $F(1, 22) = 51.81, p < .001, \eta_p^2 = .702$. Bonferroni-corrected t -tests confirmed that the

difference in reaction time between the small and large inducers was significant for the physical inducers ($p < .001$), but not for the word cues ($p = .348$). In other words, even with the reference frames and thus potential interference removed, physical but not conceptual cues were effective in exogenously modulating the size of the attentional spotlight.

EXPERIMENT 3

Across the previous two experiments we have seen no evidence that words were capable of modulating the size of the attentional spotlight. However, one reason why this could have been the case is because we had been using a single inducer-to-target onset asynchrony (200ms). While this is in the ideal region for producing modulation of the spotlight in response to physical cues (Benso et al., 1998), and also sufficiently long to be capable of producing *shifts* of attention in response to concept words (Gozli, Chasteen, et al., 2013), it is perhaps not optimal to observe modulation of the attentional spotlight by conceptual cues cueing, since conceptual cueing can also be observed at much longer intervals. In fact, qualitatively different patterns of cueing have been found at short cue-target intervals (200-400 ms) compared with long intervals (800-1200 ms) (Gozli, Chasteen, et al., 2013). In Experiment 3, therefore, we varied inducer-to-target time, and adopted the following range of values: 200, 400, 800, and 1200 ms.

As before, there is reason to think that reference frames might help to provide precise coordinates for the attentional spotlight to resize to, however, on the other hand, these reference frames could also potentially cause interference in this process if, for example, the smaller one captures attention. The data from Experiments 1 and 2 did not provide any evidence to adjudicate between these two possibilities. Therefore, we varied the presence versus absence of these reference frames in order to discern the impact of their presence. Finally, since the previous two experiments had clearly

demonstrated that our experimental set-up was capable of revealing powerful modulation of spotlight size by physical inducers, we no longer included this manipulation in Experiment 3.

Method

Participants

Twenty-four participants (9 male, 15 female) participated in Experiment 3. Participants' mean age was 23.8 years ($SD = 3.6$). Three participants reported being left-handed and the rest right-handed.

Apparatus & Procedure.

The details of the apparatus and procedure were identical to Experiments 1 and 2 (the presence/absence of reference frames was a variable), except that now the physical inducer-only condition was omitted, and SOA was varied (randomly intermixed) to be one of: 200 ms, 400 ms, 800 ms, or 1200 ms. The 500 trials that were previously in the physical inducer condition was assigned to the word condition, such that the experiment still consisted of a total of 1000 trials but now all 1000 trials were devoted to the word condition. Rest breaks were now provided every 250 trials within this experimental block.

Results & Discussion

Participants' average accuracy on the catch trials accuracy was high: 98.5%. Reaction times to detect the target (see Figure 3) were submitted to a 2 (reference frame presence) x 4 (SOA) x 2 (concept size) repeated-measures ANOVA. We applied the Greenhouse-Geisser correction for sphericity where appropriate. This revealed a significant main effect of reference frame presence, $F(1, 23) = 11.77$, $p = .002$, $\eta_p^2 = .339$, such that responses were on average quicker when reference frames were present (338ms) than when they were absent (344ms), and a significant main effect of SOA, $F(1.59, 36.49)$

= 32.99, $p < .001$, $\eta_p^2 = .589$, likely reflecting the slower responses for the 200ms SOA apparent in Figure 3. No other effects or interactions reached significance ($ps \geq .204$ & $\eta_p^2 \leq .065$). In other words, there was no evidence that concept word meaning altered the size of the attentional spotlight.

Figure 3. Reaction time to detect the onset of the target as a function of reference frame presence, stimulus-onset asynchrony (SOA) between the cue and target, and concept word meaning size (small or large) in Experiment 3. Error bars represent standard errors of the mean corrected for within-subjects designs (Cousineau, 2005).

None of the interactions involving concept size were significant. However, an alternative way to analyse the data is to look for whether there are reliable differences between the small and large conditions regardless. Such local comparisons should of course be corrected for multiple comparisons in order to ensure that Type I error rate is not inflated. Here there would be eight such comparisons, and thus the critical alpha level would = .00625. None of the comparisons were statistically reliable, confirming

the conclusion arising main analysis: that concept words did not change the size of the spotlight.

SOA (ms):	200	400	800	1200
Reference	.085	.597	.268	.376
frames present:				
Reference	.938	.686	.882	.039
frames absent:				

Table 1. *p*-values for each of the local small versus large comparisons (repeated measures *t*-tests) for each condition. Critical alpha = .00625. None of these values meet this criterion for significance.

EXPERIMENT 4

In the previous experiments the concept words referred *directly* to size (*small*, *little*, *big*, and *large*), whereas in the conceptual cueing literature with shifts of attention, the cues have more indirectly referred to or been associated with spatial locations (e.g., *sun* and *joy* for up, and *grass* and *bitter* for down). It is possible that the most effective cues for modulating the size of the attentional spotlight are those that more indirectly refer to size. For this experiment, therefore, we selected conceptual terms that were abstractly related to or indirectly referred to size (e.g., *mouse* versus *elephant* and *pea* versus *earth*).

Participants

Twenty-four participants (10 male, 14 female) participated in Experiment 4. Their mean age was 25.0 years (SD = 8.7). Two participants reported being left-handed and the remainder right-handed.

Stimuli

The goal of stimulus selection was to achieve of one list of concept words related to small/little, and another list of concept words related to large/big. To achieve this, initial word lists were generated (based on introspection/intuition) to be selectively associated with small and large (which, notably, is typically the sole criterion for classification of items in studies of conceptual cueing), and then these selections were objectively refined and verified according to latent semantic analysis (LSA), which indicated that the concept words were indeed linguistically related to small versus large.

More specifically, LSA employs singular value decomposition to provide a metric of the relationship or similarity of meaning between concepts, which does not depend on word order and syntactic structure (Dumais, 2005; Landauer, Foltz, & Darrell, 1998). The higher the value it produces the more frequently the two concepts are likely to occur together. We used a *general reading up to first-year college* topic space with a *term-to-term* comparison type (see <http://lsa.colorado.edu/>). We assessed the relationship between the potential concept words and six test items (*small, little, tiny*), and (*big, large, and huge*). For each concept word, we calculated the average association between the word and the three items related to small, and the average association between the word and the three items related to large, and then took the difference between these two averages, such that a larger absolute difference score indicates a greater association with a given size term. The direction of the difference score (positive or negative) indicates which size term (small or large) the concept term is associated with. Simply due to the way we calculated it, positive scores indicate an association with small sizes, and negative scores indicate an association with large sizes. The difference scores for the final word lists can be seen in table 1.

The criteria for final word selection list were: (1) that the difference scores for the generated items had to be in the direction that the intuitive understanding of concept would predict, (2) that the final lists did not significantly differ on overall frequency of word use in written English ($p = .194$), as measured by Google Ngram, set to the most 10 years recent years of data available, 1998-2008, case-insensitive (Michel et al., 2011). Some items did appear to contravene the first criterion in interesting ways – for example, *marble* was initially selected as a small item, actually had a reasonably strong ($-.08$) association with the large dimension (perhaps due to large marble edifices, rather than the small round children’s toy we were thinking of), and some items such as *Neptune*, which were anticipated to be associated with large, had a 0 difference score, indicating that it had no systematic association with either small or large. This highlights the importance of not relying solely on experimenters’ intuition to classify items (see also Goodhew & Kidd, in press)). Table 2 shows that all of the final items, however, appeared to have clear and logical associations. Furthermore, these were supported statistically: the differences scores for both small ($p < .001$) and large ($p < .001$) concepts were significantly different from zero.

Concept term	Difference score
Mammoth	-.17
Elephant	-.15
Monster	-.14
Truck	-.11
Land	-.10
Ocean	-.07
Earth	-.06

Dragon	-.05
Butterfly	.13
Flea	.09
Egg	.09
Pea	.08
Seed	.07
Mouse	.07
Eye	.06
Coin	.02

Table 2. Concept items associated with large versus small, and their association difference scores derived from LSA. Negative difference scores indicate associations with the concept *large/big/huge*, whereas positive difference scores indicate associations with concept *small/little/tiny*. The magnitude of the difference score indicates the strength of the association.

Apparatus & Procedure

All aspects of the apparatus and procedure were identical to Experiments 3, with two notable exceptions. Now the concept words were changed to the 16 items showed in Table 1. Furthermore, the four SOAs were reduced to two: 360ms and 1000ms.

Results & Discussion

Average performance on the catch trials was high: 98%. Reaction time to detect the target was submitted to a 2 (reference frame presence) x 2 (SOA) x (concept size)

repeated-measures ANOVA. This revealed a significant main effect of reference frame presence, $F(1, 23) = 4.94$, $p = .036$, $\eta_p^2 = .177$, such that responses were faster when the response frames were present (346ms) than when they were absent (356ms). There was also a significant main effect of SOA, $F(1, 23) = 35.18$, $p < .001$, $\eta_p^2 = .605$, such that responses were faster at the 1000ms SOA (289ms) than at 360ms SOA (338ms). There was no main effect of concept size ($F < 1$). The interaction between reference frame presence and SOA approached significance, $F(1, 23) = 4.03$, $p = .057$, $\eta_p^2 = .149$. None of other the interactions were or approached significance ($ps \geq .148$ & $\eta_p^2 \leq .089$). Altogether then, concept size did not modulate the size of the attentional spotlight.

Figure 4. Reaction time to detect the onset of the target as a function of reference frame presence, stimulus-onset asynchrony (SOA) between the cue and target, and concept word meaning size (small or large) in Experiment 4. Error bars represent standard errors of the mean corrected for within-subjects designs (Cousineau, 2005).

Once again, concept size did not interact with any of the other variables. Despite this, however, one could argue that a more complete approach to the analysis also includes examining the local small versus large comparisons. Experiment 4 requires four such comparisons, and thus the critical alpha level is .0125. The p -values for each of the comparisons can be seen in Table 3. None were reliable. This confirms that concept words do not modulate the size of the attentional spotlight.

SOA (ms):	360	1000
Reference frames present:	.788	.026
Reference frames absent:	.773	.310

Table 3. p -values for each of the local small versus large comparisons (repeated measures t -tests) for each condition. Critical alpha = .0125. None of these values meet this criterion for significance.

EXPERIMENT 5

Thus far across four experiments we have seen no evidence that concepts are capable of modulating the size of the attentional spotlight, whereas the physical inducers used in Experiments 1 and 2 exerted powerful effects on the speed of target detection. This was true even though we had varied a wide variety of candidate necessary conditions for observing an effect of concept words, including a wide range of SOAs, words that directly versus indirectly refer to size, and the presence and absence of physical reference frames. There remains, however, one outstanding possibility: that peripheral

presentation of targets is necessary. That is, all of the experiments so far have shared in common the central presentation of target stimuli. We know from both previous research (Benso et al., 1998) and from Experiments 1 and 2 in the present study that peripheral presentation of targets is not a necessary condition to observe substantial modulation of target detection speed when physical inducers are used. It is still theoretically possible, however, that conceptually-driven spotlight size modulation may be weaker, and thus could require uncertainty with respect to target location in order of attentional modulation effects to be observed. Indeed, in typical conceptual cueing studies, *shifts* of attention are usually measured with peripheral and uncertain location targets (e.g., Chasteen et al., 2010; Goodhew et al., 2014; Gozli, Chasteen, et al., 2013). In Experiment 5, therefore, we varied target location: to be either central, inner location (i.e., slightly to the left or right of centre), or an outer location (substantial deviation to the left or right of centre).

In addition to permitting us to examine of the effect of peripheral targets and target location uncertainty, this manipulation also serves as a second, convergent method of providing participants with clear reference points for what constitutes ‘small’ versus ‘large’ with respect to spotlight size. While the reference frames used in the previous studies were designed to do this, it is possible that manipulating target location – a dimension of the stimulus that is directly relevant to participants’ task – would be a more effective reference frame for participants than showing them both sizes simultaneously on a trial.

Method

Participants

Twenty-four participants (3 male, 21 female) participated in Experiment 5. Participants' mean age was 21.5 years ($SD = 3.5$). Two participants reported being left-handed and the remainder right-handed.

Stimuli, apparatus, and procedure

Details of the stimuli, apparatus, and procedure were identical to Experiment 4 except for the following changes. Target location was varied, such that targets could now appear centrally, at inner locations (0.5° deviation to the left or right of centre), or outer locations (8° deviation to the left or right of centre). Our choice of inner and outer target distances was motivated by the aim to provide participants with clear reference frames for small versus large spotlights. This means that we wanted the inner stimuli to fit within bounds of a small attentional spotlight, and the outer locations to sufficiently eccentric to a) be confident that not within small spotlight and b) reveal reliable differences in performance to the small spotlight. We chose 0.5° either side of fixation in particular for the inner locations because previous research has estimated the size of a small attentional spotlight to be about 1° diameter (Eriksen & Hoffman, 1972), and we chose 8° specifically for the outer distance because a) this is a common fixation-to-target distance successfully employed in gauging *shifts* of attention in response to conceptual cues (e.g., Goodhew et al., 2014; Gozli, Chasteen, et al., 2013), and b) this would reasonably be expected to be discernibly different to the inner location. These five target locations (central, 2 inner, 2 outer) all occurred with equal probability across the experiment. The presentation of physical reference frames was eliminated, since now target location should serve the reference for different sizes, whereby inner locations mark the bounds of a small spotlight and outer locations mark the bounds of the large spotlight. The words used consisted of a mix of direct and indirect references

to size. Specifically, *coin* was swapped for *small*, and *eye* for *little*, *dragon* for *large*, and *earth* for *big*.

Results & Discussion

Participants' average accuracy on the catch trial was very high: 98%. Reaction times to detect the target are shown in Figure 5. These values were submitted to a 3 (target location) x 2 (SOA) x 2 (concept size) repeated-measures ANOVA. We applied the Greenhouse-Geisser correction for sphericity where appropriate. This analysis revealed a significant main effect of target location, $F(1.59, 36.62) = 47.42, p < .001, \eta_p^2 = .673$, reflecting that responses were quicker for central (350 ms) and inner target locations (351 ms) relative to outer target locations (371 ms). There was also a significant main effect of SOA, $F(1, 23) = 10.89, p = .003, \eta_p^2 = .321$, such that responses were faster for 1000 ms SOA trials (351 ms) than for the 360 ms SOA trials (363 ms). There was no main effect of concept size ($F < 1$). There was a weak trend toward an interaction between target location and SOA, $F(1.87, 42.96) = 2.90, p = .065, \eta_p^2 = .112$. None of the interactions were significant ($Fs < 2.77$ and $ps > .073$). In other words, the results indicated that concept words did not change the size of the attentional spotlight.

Figure 5. Reaction time to detect the onset of the target as a function of target location, stimulus-onset asynchrony (SOA) between the cue and target, and concept word meaning size (small or large) in Experiment 5. Error bars represent standard errors of the mean corrected for within-subjects designs (Cousineau, 2005).

Moreover, we once again performed multiple local comparisons between the small and large spotlight conditions. We made six such comparisons, and thus the critical alpha level = .008. The p -values for these comparisons for Experiment 5 can be seen in Table 4. None of these comparisons survived correction, thereby confirming the results of the main analysis. Concept words do not modulate the size of the spotlight.

SOA (ms):	360	1000
Centre targets:	.125	.292

Inner targets:	.204	.573
Outer targets:	.635	.944

Table 4. p -values for each of the local small versus large comparisons (repeated measures t -tests) for each condition. Critical alpha = .008. None of these values meet this criterion for significance.

Next we sought to check whether there was a difference between the direct and indirect spatial terms. To do this, we split the data according to whether the spatial words directly referred to size (*small, little, big, large*), or indirectly referred to size (e.g., *mouse, elephant*), and repeated the analysis. For direct spatial words, there was a significant main effect of target location, $F(1.47, 33.89) = 15.29, p < .001, \eta_p^2 = .399$, and of SOA, $F(1, 23) = 9.37, p = .006, \eta_p^2 = .289$. There was no main effect of concept size ($F < 1$). None of the interactions reached significance ($F_s < 1.88$ and $p_s > .169$). For indirect spatial words, there was a significant main effect of target location, $F(1.77, 40.73) = 44.74, p < .001, \eta_p^2 = .660$, and a significant main effect of SOA, $F(1, 23) = 9.50, p = .005, \eta_p^2 = .292$. The main effect of concept size was not significant ($F < 1$). None of the interactions reached significance ($F_s < 2.47$ and $p_s > .101$). To summarise, it did not matter whether the concept words directly or indirectly referred to size, they did not modulate the size of the spotlight.

Finally, since it may have taken participants some time to learn where the different target locations were in order for them to be effective reference points for the bounds of different spotlight sizes, we then analysed participants' second half (500

trials) of the experiment (averaging across direct and indirect spatial words). Here there was once again a significant main effect of target location, $F(1.99, 45.74) = 30.01, p < .001, \eta_p^2 = .566$, and of SOA, $F(1, 23) = 11.97, p = .002, \eta_p^2 = .342$, and not of concept size, $F(1, 23) = 1.70, p = .205, \eta_p^2 = .069$. There was a weak but not reliable pattern for target location and SOA to interact, $F(1.46, 33.57) = 2.67, p = .099, \eta_p^2 = .104$. None of the other interactions approached significance (F s < 1.66 and p s $> .210$). Altogether, there was no evidence that concept words affected reaction time and therefore no evidence that they modulated the size of the attentional spotlight.

General Discussion

Across five experiments, we found no evidence that concept words that referred either directly (e.g., *small, large*), or were indirectly related to size (e.g., *mouse, elephant*) were able to influence the size of the attended region. This was true despite the fact that physical inducers were clearly powerfully able to alter attentional spotlight size. Of course, here we are making a conclusion on the basis of ‘null’ (no difference between the two concept size conditions) results. Null results can never definitively confirm a conclusion, but can fail to support one, as we have here. However, through extensive and well-conducted testing, repeated failures to support conclusions can be informative, as we believe that they are here. We tested the ability of concept words of both direct and indirect size meaning, and we tested multiple different cue-target SOAs over an extensive range of durations, and with different target locations, all in experimental parameters amply able to reveal strong results. Yet we saw no evidence to support the notion that concept words can alter the size of the attentional spotlight. We think that this warrants the conclusion that concept words do not change attentional spotlight size.

Why, then, is conceptual cueing observed in relation to shifts of attention, but not in relation to changes in the size of the attention spotlight? One possibility is the lack of specificity regarding the physical coordinates to which the concepts refer. That is, when participants read the word *small*, they might have been unclear about how small to scale to, and similarly, when participants read the word *large*, they might have been unclear about how large to scale to. We think that this is not a critical problem because even if there was some lack of specificity, there was no requirement for participants' small and large spotlights to be any particular size, only the requirement that the adoption of their *small* spotlight be smaller than their *large* spotlights. Indeed, even reasonably modest differences in physically-induced spotlight size can produce substantial effects on reaction time (Benso et al., 1998). Furthermore, we also provided participants with explicit reference frames to assist this process in Experiments 1-4, and target location served as a proxy reference frame in Experiment 5. While participants' responses were slightly quicker on the trials on which the reference frames were present, suggesting it led to a slight small-spotlight bias, it means nonetheless that even in Experiments 3 and 4 where participants no longer completed the physical-inducer blocks, participants were still completing reference-absent trials conceptual-inducer trials in the context of where their spotlights were being altered to be measurably small and large (by the reference-frame present trials). Furthermore, in the selection of stimulus words for Experiments 4 (also used in Experiment 5), we deliberately chose small concrete objects that would be small even in relation to the computer screen. Some of the shortlisted objects had strong associations with the dimension of small, as revealed by the LSA (e.g., *kitten*). But even a small kitten could be quite large in relation to attentional spotlight applied to the computer screen in front of the participant, and these items were thus rejected from the final lists. Whereas *butterfly*, *flea*, *egg*, *pea*,

seed, *mouse*, *eye*, and *coin*, would all be small in relation to the screen, and the large items (e.g. *elephant*, *truck*, etc) were all very large. Thus, we do not think that there was a critical lack of specificity in the items or the task itself. Most crucially, recall that shifts of attention (upward/downward in space) occur in response to abstract words such as *joy*, *bliss*, *dream*, *doom*, *hostile*, and *bitter*, despite these items having no location in space, and thus zero spatial specificity. Thus, a systematic difference in spatial specificity cannot explain the different pattern of results in the present task compared with that observed in previous conceptual cueing research. Instead, we think that the evidence warrants the conclusion that concept words do not modulate the size of the attentional spotlight – only physical inducers – that is, objects, do.

These findings therefore have important theoretical implications for theories about the mechanisms underlying the regulation of changes in the size of the attentional spotlight versus changes in its location. The fact that concept words shift attention but do not alter spotlight size points to distinct mechanisms underlying these two fundamental attentional processes. The existing literature indicates that changes in the location of the attentional spotlight implicate a trade-off in the two major visual pathways, such that there is an enhancement in parvocellular-mediated visual perception (which subserves finely-detailed spatial vision), but an impairment in magnocellular-mediated perception (which underlies temporal acuity and motion perception) at the attended location (Yeshurun & Levy, 2003; Yeshurun & Marom, 2008; Yeshurun & Sabo, 2012). Researchers have implicitly assumed a similar-trade-off underlies changes in spotlight size (Bush & Vecera, 2014). In contrast, however, preliminary evidence suggests that for changes in the size of the attentional spotlight, there is modulations only in parvocellular-mediated visual perception, while magnocellular-mediated perception is left unchanged (Goodhew et al., in press). This

led to the development of the theory of *selective spatial enhancement* – the notion that changes in attentional spotlight size modulate only spatial acuity (and not temporal acuity) for functional reasons: because it is spatial acuity that declines so rapidly in the visual periphery, whereas temporal acuity is not impaired or is even enhanced (Goodhew et al., in press). The fact that evidence from the current study suggests that conceptual cues are exclusively effective in instigating shifts but not changes in the size of the spotlight is also converging evidence for them having distinct underlying mechanisms, and therefore, is broadly consistent with the theory of selective spatial enhancement.

While the present study suggests that for unselected participants, concept words do not change the size of the attended region, there still remains the possibility that this effect might occur for specific subgroups of individuals. For examples, synaesthetes are individuals who experience unusual sensory associations, most commonly such as experiencing letters as words as colours (e.g., blue Monday, green Friday) (Galton, 1880; Mattingley, Rich, Yelland, & Bradshaw, 2001; Simner, 2007). Recent evidence shows that synaesthetes experience greater semantic priming relative to controls, indicative of enhanced encoding of semantic relations (Goodhew, Freire, & Edwards, 2015). Given the emerging consensus regarding the linguistic basis to conceptual cueing (Goodhew et al., 2014; Hutchinson & Louwerse, 2013; Louwerse, 2008; Louwerse & Jeuniaux, 2010), this raises the possibility that synaesthetes might be sensitive the effect of conceptual inducers in altering spotlight size in a way that non-synaesthetes are not. This could be addressed in future research.

In conclusion, physical inducers of different sizes change the size of the attentional spotlight, whereas words do not appear to have this power. Put another way, objects but not concepts change the size of the spotlight. This means that, for example,

thinking about an elephant or a mouse is not sufficient to rescale the size of the attended region, but instead one would have to see one these objects for this process to occur.

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