Contextual Cueing in Virtual Reality: The Influences of Attentional Asymmetry Across Depth on Learning of Depth-Defined Spatial Regularities

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Certificate of Originality

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of high learning, except where due acknowledgement is made in the text.

I also declare that the intellectual content of this thesis is the product of my own work, even though I may have received assistance from others on style, presentation, and language expression.

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Abstract

The contextual cueing effect is the enhancement in target localisation performance during visual search when exposed to repeated compared to random configurations of distractors, which demonstrates how sensitivity to unchanging information can be advantageous. As learning of every cue within a context requires an elaborate effort, selective attention is key to help us filter and select for information to learn. Though studies examining the encoding of depth information in spatial representation have yielded mixed findings, work on attention has revealed an attentional asymmetry across depth. The current experiments attempted to resolve the opposing stances on the role of depth information through examining the effects of attentional asymmetry on the contextual cueing effect in virtual reality. The first set of experiments (1a & 1b) trained participants on repeating and random configurations with both near and far targets spread across depth. Results demonstrated a stable cueing effect was established but this cueing effect did not differ between near and far targets. Experiment 2 examined the learning of egocentric and allocentric contingencies between target and repeating information. No difference in the size of cueing effects were found between proximal and distal allocentric representations of target-distractor associations across depth. A stronger learning was however, observed when both reoccurring information and target were consistently presented further away, suggesting that contexts may be coded with an egocentric system. Implications of spatial attentional bias, prioritisation of learning and a parallel representational system with regards to contextual learning are discussed.

Imagine walking into an office. As soon as you switch on the lights, you hear the phone ring. You rush towards the desk just in time to pick it up and are informed of an important meeting later in the day. Taken aback, you quickly grab a mug sitting at the corner of the desk and head towards the kitchen to make yourself a cup of coffee in preparation for a long, busy day. Consider the situation above, and how the efficient search of these objects contributed to a smooth progression of your day. How do humans learn to build these spatial maps of the relevant features of their environment?

"Context" plays an important role in visual search. Specifically, a coherent environment or set of spatial regularities (which will be referred to as the *context*) can facilitate search (Bar & Ullman, 1996; Biederman, 1972). For example, in the scenario described above, light switches are more likely to be located on the wall next to the door than across the room; phones and mugs are expected to be situated on top of desks rather than on the ground or on top of a shelf. Sensitivity to the regularities in our environment can further act to guide attention and facilitate learning (Chun, 2000; Zhao et al., 2012). This promotion of efficient search through the acquisition of contextual representation is termed contextual cueing (Chun, 2000; Chun & Jiang, 1998; Olson & Chun, 2002; Peterson & Kramer, 2001).

The Contextual Cueing Effect

Chun and Jiang (1998) were the first to demonstrate contextual cueing through a simple visual search paradigm. Participants were told to search for a target 'T' embedded amongst distractor 'L's and to report the orientation of the target (Figure 1). Unbeknownst to the participants, half of the configurations of distractors were repeated throughout the experiment. These repeating configurations (often termed 'old') were intermixed with configurations that were randomly arranged on each trial. Over time, participants showed an overall improvement in search performance, but more importantly, this facilitation was more pronounced for 'old' contexts compared to 'new' contexts – demonstrating the contextual cueing effect. Therefore, the operational definition of contextual cueing was the differences in search time between 'old' and 'new' contexts. Participants also reported no explicit memory of the repeated contexts, suggesting that the contextual cueing effect was a form of implicit learning (Chua & Chun, 2003; Chun & Jiang, 1999, 2003; Goujon, Didierjean, & Thorpe, 2015; Kawahara, 2003).

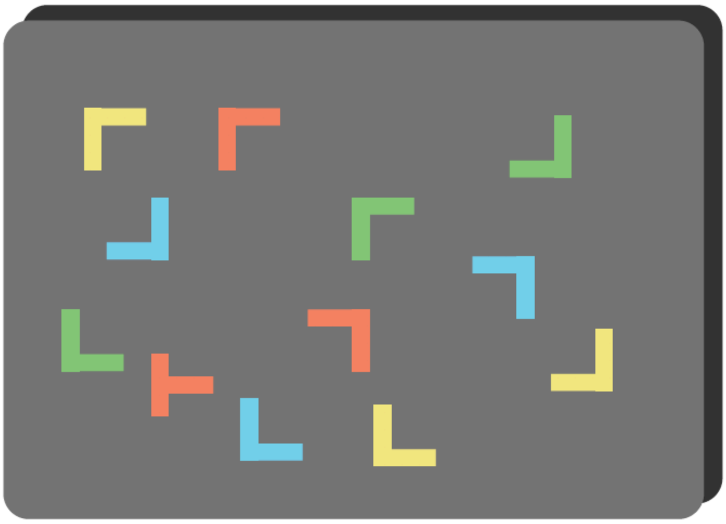

Figure 1. Schematic representation of a contextual cueing trial drawn from Chun (2000). Distractor 'L's formed the context and 'T' was the target. Participants were to respond to the orientation of the target 'T'.

Since then, many studies have further investigated the properties of the contextual cueing phenomenon. The contextual cueing effect had proven itself to be robust, manifesting in the form of learning of novel shapes and trajectories (Chun & Jiang, 1999), regardless of distractor identity (Conci & Mühlenen, 2009; Olson & Chun, 2002), has long-term retention effects (Chun & Jiang, 2003), in both parallel and serial searches (Geyer, Zehetleitner, & Müller, 2010), and in children (Darby, Burling, & Yoshida, 2014). Furthermore, contextual memory acquired from preceding trials were shown to be retained and used to guide target search in subsequent trials (Ono, Jiang, & Kawahara, 2005).

The Role of Implicit Learning

Implicit learning, the ability to learn incidentally and without conscious awareness, has been implicated as the learning process of spatial representations of contexts. The main properties of implicit learning are defined as follow: (a) the knowledge acquired reflects abstract representations of the environment; (b) it operates outside of conscious effort; and (c) such knowledge can be utilised to assist the individual to problem solve and interact with novel stimuli or environments (Millward & Reber, 1972; Reber, 1989).

Early evidence for implicit learning in the contextual cueing effect was provided by inferences drawn from participants failing to perform at above chance level of recognition on various explicit memory tests. Conventional tests involved participants being shown configurations that were either repeated from the experiment or newly generated and participants were to determine whether the configuration was 'old' or 'new' (also known as the 'recognition task') (Chun & Jiang, 1998; Chun & Nakayama, 2000; Chun & Phelps, 1999; Olson & Chun, 2002) or to decide where the target would be for a given configuration (also known as the 'guessing task') (Chua & Chun, 2003; Chun & Jiang, 2003). In the case of the latter, targets were removed and replaced by a distractor during the presentation of those configurations. Compared to the recognition task, the guessing task was considered as a more valid and sensitive test of implicit knowledge due to its similarity to the main search task. This is because it tests the learnt associations between the distractor and target positions, which is critical to the contextual cueing effect, by eliciting similar processes and performances from both the main and awareness tasks. In turn, this would yield inferences which are more accurate in determining the nature of contextual knowledge (Chun & Jiang, 2003).

Chun and Jiang (2003) further established that the contextual cueing effect was due to an acquired implicit representation of configurations by testing the memory representations in accordance to well established implicit knowledge properties. These include the insensitivity to explicit instructions to memorise configurations and a long-term retention of learning. Chun and Jiang (2003) found that explicit instructions did not lead to an increase of learning compared to participants who did not receive instructions. When tested one week later, participants readily recalled and used the learnt spatial representations to guide their performance. Also, contextual knowledge was immediately available to the individual after a week as it did not require prior pre-exposure of the learnt contexts for the cueing effect to gradually manifest again. In other words, the cueing effect demonstrated at the beginning of a test period given one week later was comparable to performances at the end of the learning period. The role of implicit learning in the contextual cueing effect was also further reinforced by additional tests of properties which were characteristically different to explicit learning (Goujon et al., 2015). These include gradual emergence with practice (Tseng & Lleras, 2013) and insensitivity to IQ (Merrill, Conners, Yang, & Weathington, 2014), automaticity (Jiménez & Vázquez, 2011), age effects (Darby et al., 2014), psychiatric and neurological disorders (Howard, Howard, Japiksead, & Edende, 2006; Lamy, Goshen-Kosover, Aviani, Harari, & Levkovitz, 2008). Altogether, these studies provided strong evidence that the learning of spatial relationships within a context was implicit.

Attentional Guidance on Cueing Effect

Learning of spatial regularities involves encoding the relationships between objects in each context. However, as the learning of context is a laborious process, there is a need for a mechanism to help us filter and select for information. Attention plays a major role in determining which aspects of sensory input are processed and learnt. There is a bi-directional relationship between attention and learning – we learn more about the things we pay attention to, and this learning consequently biases our attention in the future (Anderson, Laurent, & Yantis, 2011). Jungé, Scholl, and Chun (2007) observed a primacy effect of the contextual cueing effect. Viewers were either first trained on configurations that were predictive of a target location followed by non-predictive configurations, or the reverse. A contextual cueing effect was observed when predictive configurations were presented first. The reverse order however, did not elicit a cueing effect. Moreover, when participants were told to pay attention to a selection of distractors in a specified colour, a contextual cueing effect was only evident when predictive information was presented in the attended colour (Jiang & Chun, 2001; Kawahara, 2003). Nevertheless, spillover effects of attention were also observed (Jiang & Leung, 2005). For example, Jiang & Leung (2005) trained participants to pay attention to a set of coloured distractors. A facilitation in search speed was observed when the attended set was repeated, but not for the ignored set. Then, during a transfer test where participants were now told to attend to the previously ignored set, a similar enhancement in search performance was observed. This suggests when predictive information was only available in the ignored stream, latent learning of information was possible.

Local vs. Global Context

A body of work in the contextual cueing literature has attempted to examine the extent of learning of contextual information across space. Recent research suggested there is an unequal sensitivity to various aspects of a context. Olson and Chun (2002) segmented their display into two halves and local contexts were defined where the repeated distractors shared the same half of the screen as the target (Figure 2). Long-range contexts on the other hand, had repeated distractors found on the opposite side of the screen to the target. Observers were trained on repetitions of either contexts and a facilitation in target localisation was observed when local information were repeated. Long-range contexts had been shown to also facilitate search only when there is no extraneous information, such as non-predictive distractors, segregating it from the target. This result demonstrated two important findings – first, the implicit learning of visual context is sensitive enough to parse noise from signal within a given context and second, perceptual constraints limited to spatially proximal objects influence the information that is processed and encoded into our spatial maps.

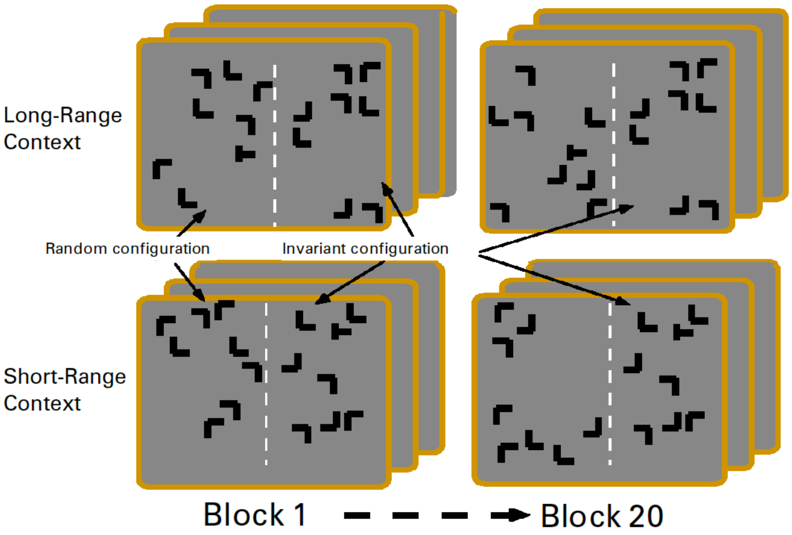

Figure 2. Operationalisation of global and local contexts by Olson and Chun (2002). Long-Range Context trials repeated distractors on the opposite side of the screen in relation to target ‘T’ location; whereas Short-Range Context (local context) trials had the repeating distractors on the same side of the screen as the target.

Jiang and Wagner (2004) attempted to investigate the type of stimulus associations learned in contextual cueing paradigms. They trained participants on trials where the same target position could be equally predicted by two different repeated configurations. Participants then transitioned to recombination trials, where for any given target, each configuration was made up of half the distractors from each of the two previously trained repeated configurations. Half of the distractors were drawn from one old repeated configuration and the other half from the other old configuration. When the reaction times of recombined trials were compared to participants that experienced repeated but not recombined trials, no significant differences were found. This implied individual target-distractor associations were acquired and were sufficient to sustain the contextual cueing effect; despite a disrupted global configuration.

Repetitions of only a small part of the display, however, was not sufficient to construct a strong spatial representation of contexts to drive the contextual cueing effect. Song and Jiang (2005) first trained observers on the standard contextual cueing paradigm. This was followed by a transfer phase with configurations that either had of the stimulus locations randomised (*new*), all repeated (*old*) or only three randomly chosen locations, including the target, repeated (*3-location old*). A cueing effect was found with both *old* and *3-location old* conditions but not in *new*. This result was contrasted with another experiment of theirs where observers were trained on either *new*, *old* or *3-location old* configurations. A comparison of reaction times across all three conditions showed a significant cueing effect in *old* but not for *new* or *3-location old*, suggesting that a partial match of three locations between visual input and memory was not sufficient to sustain a cueing effect. Together, their findings indicate that at the early stages of statistical learning, invariant global contexts may be necessary in establishing an effective spatial map. Conversely, after the acquisition of a spatial map, a partial match of locations between memory and display are sufficient to sustain a cueing effect. The contextual cueing effect also remained robust when overall configurations were rescaled and displaced (Jiang & Wagner, 2004). However, as displacement and rescaled global configurations preserved local spatial relations, disruptions to perceptual grouping were introduced to distort local spatial representations. This was achieved by presenting half the distractors in green or red, and swapping them during the transfer test. As colour groupings can be formed across distance and overrides spatial relationships (Baylis & Driver, 1992), this would have interfered with the formation of local target-distractor associations. The cueing effect did not reduce as a function of disruptions to perceptual groupings (Jiang & Wagner, 2004), indicating that global contexts alone were also sufficient to drive the contextual cueing effect.

A unifying account of local and global learning was offered by Brady and Chun's (2007) computational model, the architecture of which is a two-layer neutral network. The input nodes code the presence of objects at various locations within the configuration. For each trial, the activation on the network output units reflects the likelihood of the target appearing in each location. With continuous exposure to repeated configurations (inputs), the network can adjust its weights to learn to identify the correct target location more accurately. This in turn forms a ranking of to-be-searched locations based on activation values from the output to help guide attentional deployment. Computational data was shown to be successful in replicating the general trends of the cueing effect observed in human participants of Chun and Jiang (1998). To account for the nature of learning of short and long-range contexts, their model further imposed spatial constraints on contextual learning to explain earlier conflicting findings through attentional spotlight, or focused attention. A comparison of the magnitudes of the contextual cueing effect between globally and locally repeating configurations revealed no differences between groups across both human and computational data. This suggests extra information from invariant global information does not additionally contribute to the cueing effect and reinforced that learning was bounded by an attentional spotlight whereby local information were most strongly encoded. As demonstrated by Olson and Chun (2002), when no local information around the target can be encoded, attentional scope may broaden and learning could extend to long-range global contexts. The underlying assumption of the model was that target-distractor relationships were encoded in absolute but not relative locations within a configuration. This explained why the contextual cueing effect was resilient against rescaled and displaced displays but not when local information shifted across a global context (Jiang & Wagner, 2004).

Shift from 2D to 3D Paradigms

Despite extensive research conducted on contextual cueing, there is little evidence supporting its ecological validity. That is, how well does the functional benefits of contextual cueing generated from arbitrary letter arrays in laboratories translate to the real world? Conducting experiments in our physical world is a challenging task, due to the inability to have control over all the variables present in our environment. However, technological advancements such as 3D computer monitors, augmented and virtual reality, offers the potential to experiment in realistic environments with precise control. As such, more recent studies have begun to modify traditional contextual cueing paradigms to allow targets and distractors to reflect real world scenes or situations (Brockmole, Castelhano, & Henderson, 2006; Brockmole, Hambric, Windisch, & Henderson, 2008; Brockmole & Henderson, 2006) or to examine depth (Chua & Chun, 2003; Kawahara, 2003; Zang et al., 2017). And these simple changes made to the 2D contextual cueing paradigm can result in very contrasting patterns of results. For example, by depicting real world objects and scenes in a contextual cueing paradigm, Brockmole et al. (2006) found that repetition of the global scene with local changes produced a larger contextual cueing effect compared to replicating only local information. Interestingly, changes to the global environment, whilst preserving local information, abolished the contextual cueing effect, which contradicts the findings of 2D studies (Olson & Chun, 2002). Their observations suggest when participants are presented with natural scenes, target positions are learned relative to the global environment.

Depth and Contextual Cueing

The transition from 2D to 3D stimuli enabled researchers to examine an important property of the real world that 2D laboratory studies lacked, namely *depth*. Kawahara (2003) was the first to investigate whether depth information is encoded as part of the construction of contextual spatial representations. Depth information was established through binocular disparity, where target and distractors were presented across two depth planes. When participants were instructed to selectively attend to either plane, selective attentional effects were observed. That is, contextual cueing was only evident when predictive information was presented in the attended set of distractors (Jiang & Chun, 2001). However, when the distractors on the two depth planes were reversed during test – preserving an identical 2D image yet an altered 3D layout, contextual cueing effects were abolished. This suggests that target-distractor associations were spread across 3D layouts and this relationship can facilitate contextual cueing.

This idea of encoding depth information in our spatial representations of contexts however, was challenged by Zang et al. (2017). The primary critique was Kawahara's approach of reversing only the distractors, but not the target, across the two depth planes. They pointed out that such manipulation presented itself with a confound, whereby target-distractor associations of local contexts (within a local plane) were also disrupted in the process. And as seen in earlier studies of how local information had the capability of driving a contextual cueing effect (Olson & Chun, 2002), interference to local target-distractor associations, but not depth associations, may account for the pattern of results observed by Kawahara (2003). Zang et al. (2017) devised two experiments to address the confound (Figure 3). Their first experiment corresponded to that of Kawahara (2003), where participants were trained on 3D layouts, followed by reversing all objects on the two depth planes, including the target. Similarly, in their second experiment the display was reversed as well, but this time, rather than a front-to-back reversal, it was a left-right swap. In the left-right swap, 2D spatial representations were disrupted. Surprisingly, contextual cueing was not affected by the reversal of depth planes but was eliminated after a left-right swap. Therefore, their results indicate that 2D planar target-distractor associations forms the basis of the contextual cueing effect and depth-defined spatial regularities may be regarded as unimportant and not encoded.

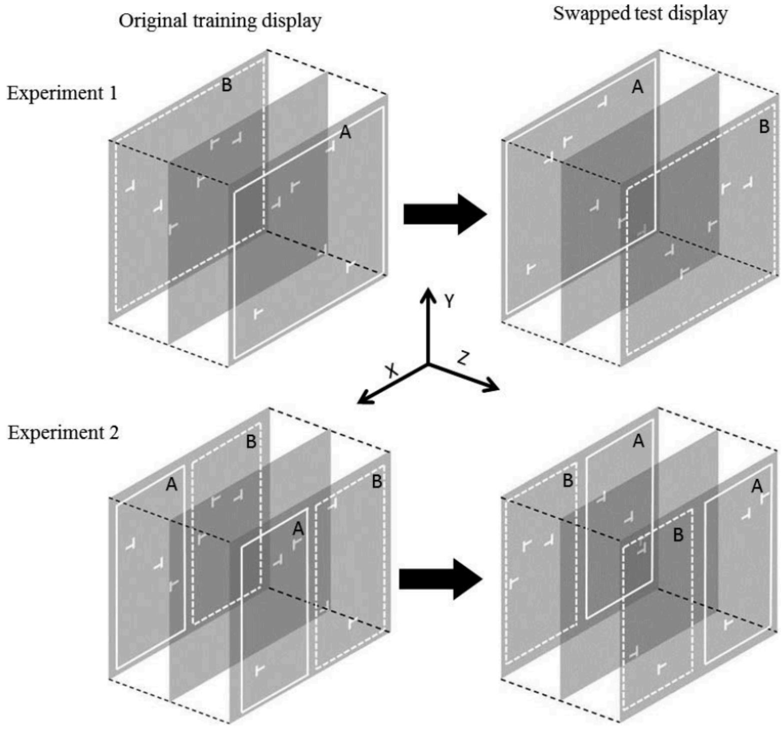

Figure 3. Experimental manipulations used by Zang, Shi, Muller, and Conci (2017). Experiment 1 had the two depth planes reversed, whereas Experiment 2 had a left-right swap within their respective depth plane.

Allocentric and Egocentric Spatial Coding

Early studies using 3D paradigms have also explored the way contextual information is processed and how associations between objects are encoded, namely allo- and egocentric spatial coding. Allocentric spatial representations are formed based on the encoding of object-to-object spatial relationships whereas egocentric representations involve the learning of self-to-object spatial relationships. Work examining 2D paradigms on attention and learning constraints assumed that contextual learning involved the acquisition of allocentric representations of the environment (without manipulating the egocentric relationships). However, more recent research on 3D stimuli has suggested otherwise. Chua and Chun

(2003) and Papenmeier and Huff (2014), transformed 2D contextual cueing stimuli into pseudo-3D images and trained participants on different 3D rotations of images of the identical scene. Participants' learning was then tested by presenting the same scene but unrotated. They found that the magnitude of the contextual cueing effect decreased with an increase in discrepancy of degree of rotation of the stimuli between training and at test. This demonstrated two important findings: first, learnt spatial regularities can be generalised to 3D contexts and second, the learning of context was viewpoint dependent.

Furthermore, when the relationship between depth and contextual cueing was examined, it was found that self-motion partly mediated viewpoint dependence (Tsuchiai, Matsumiya, Kuriki, & Shioiri, 2012). Participants were trained on a virtual display of an angular rotation of the layout. After training, participants in the "move" condition physically moved to an adjacent seat and viewed the display from a different angle. Participants in the "stay" condition remained in their seats and the display was rotated in accordance. The researchers employed the two terms: "environment-centered coordinate representation" to refer to a system that can either encode and update 3D contextual layouts through self-motion via an allocentric spatial coding system; and "retinal coordinate representation" to one where visual information are represented in egocentric 'snapshots' and are viewpoint dependent. An "environment-centered coordinate representation" would anticipate contextual cueing effects in the "move" but not in the "stay" condition, which was observed in their first experiment. However, when both the participant moved and stimulus rotated, i.e., the retinal image from both perspectives were identical, a contextual cueing effect was also observed. This lead to the acceptance of both systems' involvements in the learning of context. The researchers concluded that when egocentric coordination in the environment was lost, participants could utilize retinal coordinate representations to evaluate their positions. Importantly, the implication of egocentric representation in contextual learning further suggests that depth may be encoded.

Near and Far Regions of Space

Research has shown that there are differences on how we allocate our attention across different depth planes. Early studies on attentional distribution across 3D space indicated attention was “depth blind” (Ghirardelli & Folk, 1996). However, newer studies proposed that attention is “depth aware” (Atchley & Kramer, 1998; Atchley, Kramer, Andersen, & Theeuwes, 1997), suggesting that there are differences in attention allocated to near versus far objects. Such inferences have been made based on a larger cost in reaction time when participants were required to shift their attention across depth than across 2D space.

Gawryszewski, Riggio, Rizzolatti, and Umiltá (1987) observed an attentional asymmetry across depth. This was demonstrated through a difference in reaction time to stimuli appearing at varying depths, suggesting that attentional allocation across depth was not equal. In addition, a greater cost was found when participants shifted their attention from near to distant regions of space, compared to the reverse. Hence, they proposed that in 3D spaces, attention is allocated in a viewer-centered fashion, where the peak of attention is directed closer to the observer’s body (Miura, Shinohara, & Kanda, 2002). However, this finding contradicted another similar study (Andersen, 1990). Whilst Andersen (1990) found that attentional resources was allocated in a viewer-centred fashion, its peak was focused at locations distant from the viewer. However, Andersen was skeptical of his findings as he postulated the equipment used to create the display may have influenced the results. It was speculated that using a prism stereoscope to view stereo images may have distorted the perceived sizes of objects, in particular, the size of far objects were exaggerated; leading to a larger interference effect relative to close objects. Andersen and Kramer (1993) addressed this issue in their subsequent study by presenting stereoscopic images on a computer, viewed through polarised glasses, and obtained results that agreed with Gawryszewski et al. (1987) – attention was focused on spaces near to the viewer.

Experiment 1a & b

Given the lack of consensus, the objective of the current experiments was to reconcile the previously opposing stances on the encoding of depth information in contextual cueing. An important aspect where previous 3D studies on contextual cueing seem to have neglected was how unequal attentional distribution would affect the acquired contextual representation. To address this, we examined whether asymmetric attentional allocation across depth influences the contextual cueing effect. We chose to manipulate depth in a 3D virtual reality environment presented in a head-mounted display. Since virtual reality has not been widely used in contextual cueing paradigms, Experiments 1a & 1b aimed to ensure that a robust contextual cueing effect across depth could be achieved with this novel procedure. We also investigated whether the distance of the target, in relation to the viewer, would affect the magnitude of the contextual cueing effect. Two depths were defined in the virtual reality environment where one was near and the other further away from the participant. Repeated and random configurations were presented throughout the experiment. An equal number of distractors were distributed across the two depths and the target appeared an equal number of times both near and far away from the viewer. Experiment 1a and 1b differed mainly on the target detection mechanism, a timeout of 10s for each trial and the number of practice trials and breaks provided throughout the experiment.

In line with the existing literature, we expected to observe the typical characteristics of the contextual cueing effect. These include shorter reaction time (RT) for repeated relative to random configurations (Hypothesis 1) and an overall decrease in RT for all conditions across blocks because of practice (Hypothesis 2). In addition, we predicted that those configurations with targets closer to the viewer will have shorter RTs compared to when the target is further from the viewer (Hypothesis 3) since more attention is allocated at regions of spaces closer to the viewer (Andersen & Kramer, 1993; Gawryszewski et al., 1987; Miura et al., 2002). Given the magnitude of the contextual cueing effect has been demonstrated to be affected by set size and search time (Chun & Jiang, 1998; Zhao et al., 2012), we also expected those configurations with far targets will result in a larger contextual cueing effect, as they will require longer search times and hence more items in the context will be processed as a result (Hypothesis 4).

Experiment 1a

Method

Participants.

Twenty-six undergraduate psychology students (mean age = 19.5, *SD* = 2.0; 19 males and seven females) from University of New South Wales participated in the 1-hour study in exchange for credit points. All students were recruited via an online registration platform by the University of New South Wales – SONA. All participants were required to have normal or corrected visual acuity. Participants wearing glasses, but not contact lenses, were excluded from this experiment due to constraints with the amount of space available in the virtual reality headset.

Materials.

The “Oculus Rift VR headset (CV1)” served as the platform to deliver the experiment in virtual reality. The Oculus Rift CV1 is a head-mounted display headset that utilises a stereoscopic OLED display with 2160x1200 resolution (1080x1200 per eye) at a global refresh rate of 90 Hz, to facilitate a realistic 3D environment. Within the headset, images on the computer undergo transformations through two convex hybrid Frensel lenses, warping images and extending the environment to a wide 110° field of view. To accommodate for the varying interpupillary distances across participants, the distance between the centre of the pupils of the two eyes, the headset also has a dial that adjusts the separation of the lenses. Two external infrared “Constellation” tracking sensors were used to track the user, headset position and create the 3D space.

The experiment was programmed in the Unity engine, which created all the stimulus types, controlled timing and recorded responses. It ran on a standard computer terminal with a NVIDIA GeForce GTX 970 graphics card. All dimensions of the program were measured in Unity units[1]. The ‘spacebar’ was programmed as the response key to indicate participant’s detection responses.

Design.

This was a 2 × 2 × 10 within-subjects design with two independent variables consisting of two levels each: configuration type (repeated vs. random) and target position (near vs. far). The dependent variable was reaction time. Reaction times were measured in milliseconds (ms) from the beginning of a trial to an accepted target detection response for each trial. Any detection responses made that did not contain the target were not accepted (see below).

Virtual Reality Environment.

The virtual reality environment depicted an empty room with grey walls where the viewer was situated in the middle of the room. The program allowed objects to be placed on the surface of any of nine concentric hemispheres (see Figure 4), where the viewer (camera) was positioned at the centre of the hemispheres. Objects on each hemisphere were approximately equidistant from the observer. The first hemisphere (depth 1) was positioned 3 Unity units away from the viewer. Each hemisphere represented an increment of 2 units away from the viewer. The radius of each hemisphere also has an error range of ±0.1 Unity units.

For example, for Hemisphere 2 with a radius of 5 Unity units, objects within the hemisphere were placed somewhere between 4.9 and 5.1 Unity units from the camera. Object placement was restricted such that objects did not appear too far to the left or right of the viewer and too far above and below the viewer, resulting in a display that was similar to that of a warped plane (Appendix A). As it was possible for stimuli to appear close to the observer, head movements were required to examine the configurations and to find the target. Hemispheres 3 and 5 were chosen to portray the near and far hemispheres respectively in Experiment 1. This was decided based on considerations regarding the need to present an environment with readily detectable depth and balancing the extent of head movement required from participants to reduce experiences of neck strains and discomfort over the course of the experiment.

Stimuli presented in the experiment were 16 red cylinder-shaped distractor objects and one red pill-shaped target. All stimuli have a scale of 0.3 x 0.24 x 0.3 Unity units (x,y,z) regardless of depth[2]**.** There were no constraints on which the degrees of rotation on the x, y and z-axis for each target and distractor. In each trial, the 16 cylinder-shaped distractors were equally distributed across the two depth hemispheres, resulting in eight distractors per hemisphere (Figure 5). The target was placed in either depth hemisphere depending on the experimental condition. There were two phases in Experiment 1: practice and experimental phase.

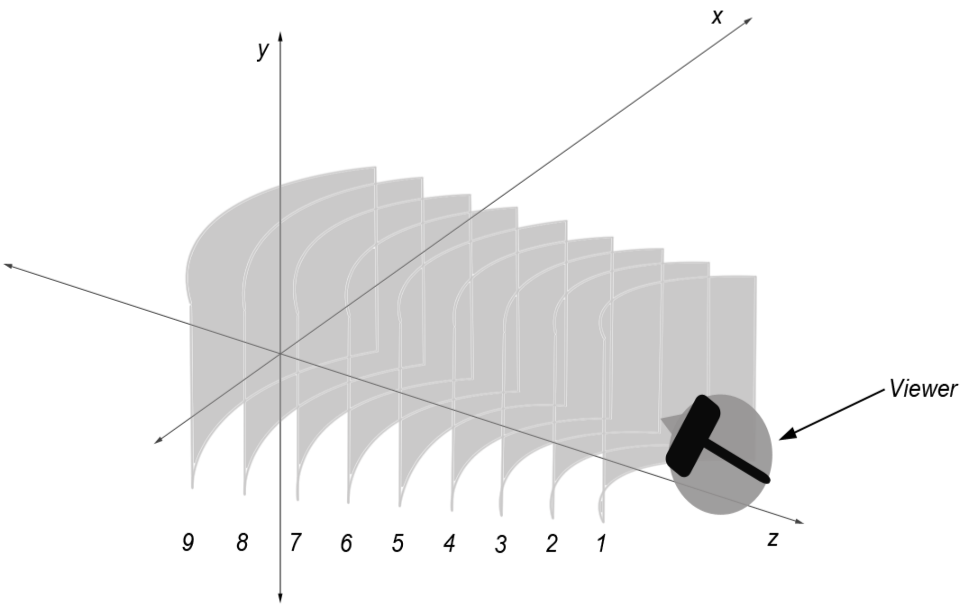

Figure 4. Schematic representation of the restricted hemispheres in relation to the viewer. Each hemisphere is 2 Unity units further away from the viewer. Hemispheres 3 and 5 were used as near and far distances in Experiment 1a & 1b.

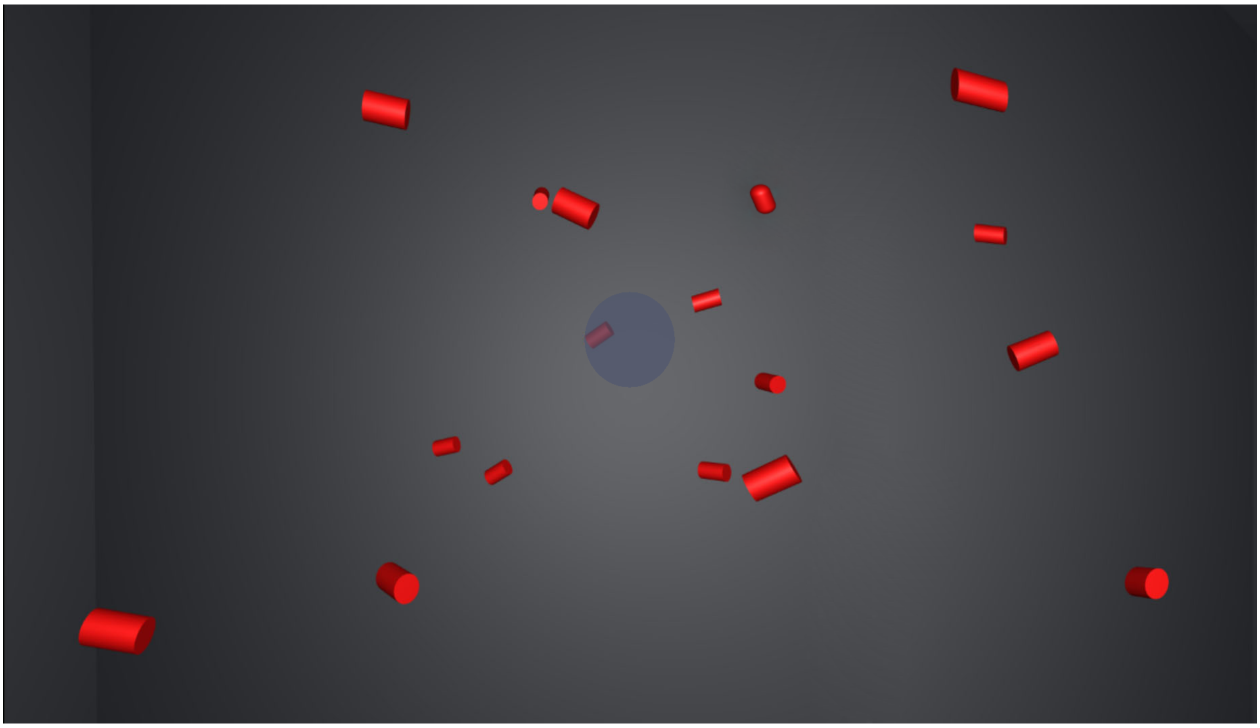

Figure 5. Panoramic screenshot of a trial. Cylinder-shaped objects were distractors and the pill-shaped object was the target. The semi-transparent blue disk acted as a guide for target localisation responses in the practice phase, but was removed for the main experiment.

Phase 1: Practice.

Participants were given 10 practice trials to familiarize themselves with the task. All configurations in the practice block were randomly generated and were unique to those presented in the experimental phase. In the practice phase, a semi-transparent blue disk, with a scale of 0.18 x 0.18 x 0.001 Unity units (x,y,z), was presented in the middle of the participant's visual field (Figure 5). This provided participants with a guide as to how they should direct their head position towards the centre of the target object, prior to responding. Only responses in which the blue circle region was over the target object were accepted. This removed the potential for participants to blindly press 'spacebar' without first locating the target object. The blue circle was used for training only and not presented in the main phase of the experiment. Between every trial a white fixation sphere, measured at 1 x 1 x 1 Unity units, appeared in the middle of the screen. Looking directly at this sphere re-centred the participant's fixation and triggered the next trial. Importantly, the blue disk was attached to the centre of the camera which allowed it to follow the participant's gaze; whereas the fixation sphere was not attached to the camera.

Phase 2: Experimental.

There was a total of 480 trials, divided into 30 blocks in the experimental phase. Each block consisted of 16 trials. Each block contained four trials of each configuration type, defined as:

- Near-repeated: Target was presented closer to the viewer, paired with repeating distractor configurations and were predictive of target location.
- Near-random: Target was presented closer to the viewer, but paired with randomised distractor configurations and were non-predictive of target location.

- Far-repeated: Target was presented further away from the viewer, paired with repeating distractor configurations that were predictive of target location.
- Far-random: Target was presented further away from the viewer, but paired with randomised distractor configurations and were non-predictive of target location.

For the two repeated conditions, four patterns each (four with target near and four with target far) were generated and presented once per block. Random configurations were generated randomly at the beginning of each block for near and far targets. The order of trials was randomised.

To control for any learning of possible target locations, target eccentricity was balanced. Four locations within a set depth, one in each quadrant, were predetermined to depict target locations for each of the repeating configurations. The same target locations were then also used in random configurations of the same depth. In phase 2, participants again were told to search for the target object, respond using ‘spacebar’ and progress as per the practice phase. Though, unlike the practice phase, the blue circle was removed from the task.

Procedure.

Prior to beginning the experimental phase, participants were presented with the practice phase to familiarize themselves with the headset and the task. Instructions were presented on screen, where participants were told to search for a pill-shaped target and to press ‘spacebar’ upon detection. Here, participants were trained with a transparent blue disk in the centre of their vision on how to produce an accepted detection response of the target. Following each successful detection of the target, participants were to redirect their fixation back to a white sphere in the middle of the screen which initiated the next trial. The experimental phase commenced after the practice trials. Participants were informed of the removal of the blue disk for the main phase. Participants were given breaks every 160 trials (at the end of every 10 blocks) and breaks lasted until participants wished to resume.

Experiment 1b

Method

Participants.

Twenty participants (mean age = 23.65, *SD* = 5.39; five males and 15 females) took part in this 1-hour study in exchange for $15. All other aspects of participant recruitment, exclusions and requirements were identical to Experiment 1a.

Design, Materials and Procedure.

Experiment 1b employed the same design, materials and procedure as Experiment 1a, with the following exceptions:

First, there were 16 practice trials instead of 10 for Experiment 1b. Second, breaks between the blocks were given every 64 trials which ensured a break at the end of every four blocks. Third, to combat issues such as occlusion and poor detection speed related to participants not being able to align the target with the centre of their visual field, a timeout after 10s was introduced. When participants failed to produce a response in 10s, the trial terminated and the word 'TIMEOUT' appeared across the screen. The white sphere then reappeared and participants were to redirect their fixation back to the white sphere and the next trial started. Experiment 1b also used an updated target detection method. In Experiment 1a, it was found that target objects in the far hemisphere were more difficult to correctly detect than objects in the near hemisphere. The new method for target detection resolved this issue which ensured there was equal difficulty in detecting objects at all depths (Appendix B).

Results

As the main task in Experiment 1a & b were identical, except for rest breaks and the target detection mechanism, the data for both experiments were combined to determine exclusions. One participant's data was removed from the analysis as it was incomplete. Of the remaining 45 participants, exclusions were performed based on the following criterion: (1) if the participant's mean number of responses (i.e., the number of times 'spacebar' was pressed within a trial) was more than 2.5 standard deviations above the sample mean; (2) if the percentage of trials with timeouts was more than 2.5 standard deviations above the sample mean; (3) if, after the removal of trials with timeouts, their mean RTs was more than 2.5 standard deviations below or above the sample mean; and (4) if, after the removal of timeout trials, the percentage of trials retained for each of the four conditions was 2.5 standard deviations below the sample mean. Even though the design of our experiment allowed for multiple responses to be made within a trial, we excluded participants who had a high number of responses per trial and timeouts since it potentially signaled that the participant consistently experienced difficulties adapting to the headset or finding the target. Two participants were excluded from the analysis for having more multiple responses than the sample mean, one participant for having a high percentage of timeout trials, and four participants were excluded for having a lower percentage of trials retained for the four conditions, one for each condition. In total, seven of the 45 participants were excluded. After exclusions, 0.92% of all combined trials were removed due to timeouts. Across each condition, 0.64% of trials from the near-repeated, 1.01% far-repeated, 0.61% near-random and 1.43% far-random were discarded.

Contextual Cueing.

All data were divided into 10 epochs, with each epoch representing the averaged RT of three blocks. The between subject factor Experiment (1a vs. 1b) and within subject factors configuration type (repeated vs. random), target position (near vs. far) and epoch (1-10) were subjected to a mixed-model ANOVA. Averaging across all within subject factors, no significant differences were observed between Experiment 1a and 1b, $F(1, 36) = 0.00$, $p = .954$, $\eta_p^2 = .00$. The between subject factor Experiment did not further interact with any of the other remaining factors, *ps* > .05. Therefore, the data were combined across the variations in experiment and a run as a 2 × 2 × 10 within-subjects ANOVA.

Participants' mean RT across all four conditions are shown in Figure 6. Analyses revealed significant main effects of configuration type, target position and block. On average, participants had shorter RTs when they were exposed to repeated configurations ($M = 2438$, $SE = 71.61$) than when they were shown random configurations ($M = 2614$, $SE = 72.19$), suggesting an overall contextual cueing effect ($F(1, 36) = 26.94$, $p < .001$, $\eta_p^2 = .43$). When the target was presented closer to the participant, a longer RT was observed in comparison to when it was further away (near target: $M = 2684$, $SE = 76.22$; far target: $M = 2368$, $SE = 74.45$), $F(1, 36) = 31.45$, $p < .001$, 95% raw CI [201.81, 430.47]. Participants also demonstrated an improvement in RT across time ($F(9, 324) = 52.81$, $p < .001$, $\eta_p^2 = .60$). A significant test of linear contrast suggested that RTs decreased as epoch increased ($F(1, 36) = 159.07$, $p < .001$, $\eta_p^2 = .82$). The Target × Epoch interaction was significant ($F(9, 324) = 2.84$, $p = .003$, $\eta_p^2 = .07$), as the difference in RTs between near and far targets increased as epoch increased in a linear fashion ($F(1, 36) = 5.84$, $p = .021$, $\eta_p^2 = .14$).

The data collapsed across the factor of epoch are presented in Figure 7. Paired sample t-test between repeated and random configurations demonstrated a significant cueing effect for near and far targets (near: $t = 3.28$, $p = .002$, [-199.84, -47.30]; far: $t = 4.65$, $p < .001$, [-329.42, -129.28]). The magnitude of the cueing effect was not significantly different between near ($M = 124$, $SE = 37.64$) and far ($M = 229$, $SE = 49.39$) targets, $F(1, 36) = 3.27$, $p = .079$, $\eta_p^2 = .08$. Returning to the main ANOVA, there was also no significant Epoch ×

Configuration interaction ($F(9, 324) = 1.69$, $p = .091$, $\eta_p^2 = .05$), indicating the cueing effect did not differ across time. All remaining two-way, three-way and four-way interactions were non-significant (*ps* > .05).

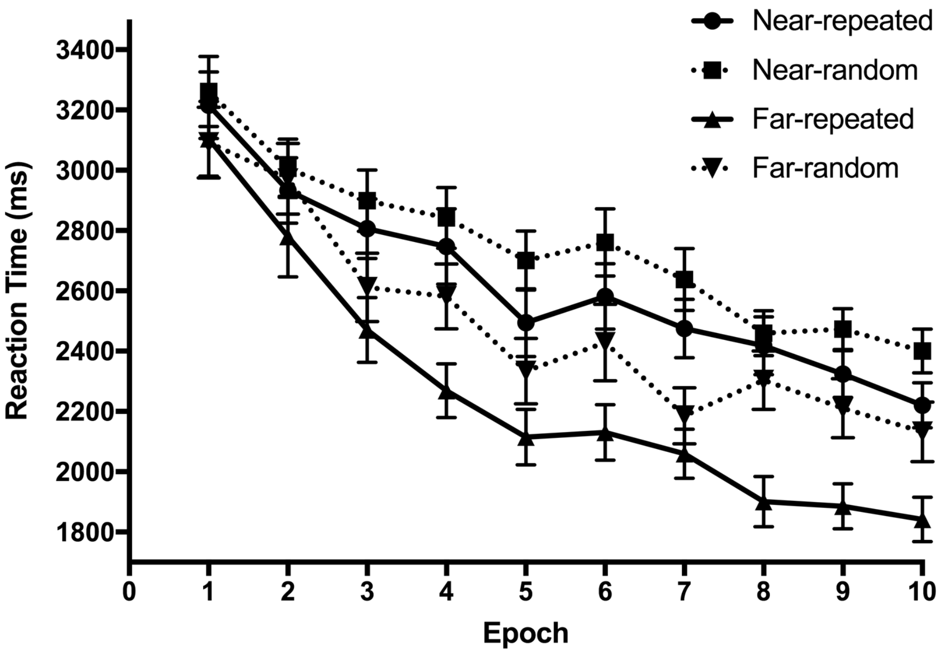

Figure 6. Mean reaction time across epochs for Near-repeated, Near-random, Far-repeated and Far-random conditions. Each epoch represented the averaged reaction of three consecutive blocks (48 trials). Error bars represented standard errors.

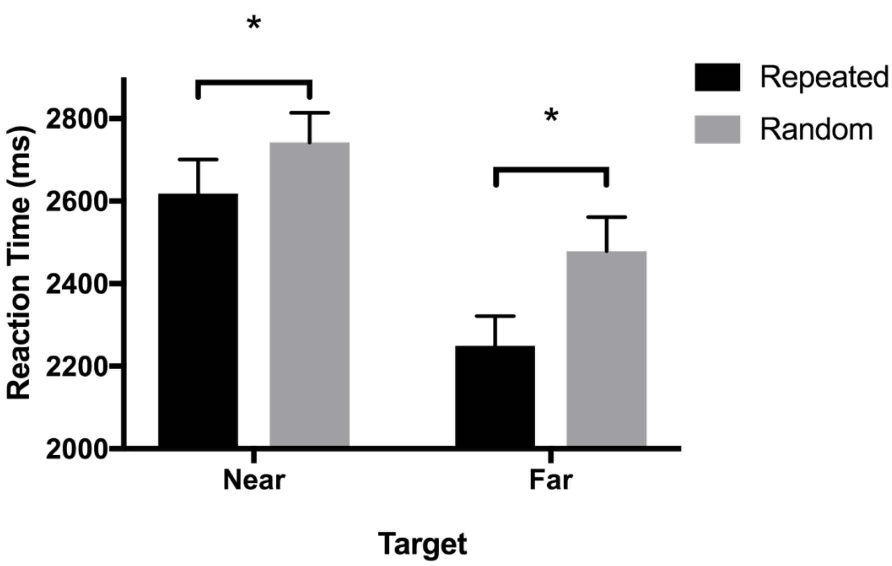

Figure 7. Mean reaction time for repeated and random configurations with near and far targets. *$p < .05$, error bars represented standard errors.

Discussion

Experiment 1 aimed to validate the use of virtual reality in contextual cueing paradigms and investigate whether targets presented at different depths produces different magnitudes of the cueing effect. Our results supported the first hypothesis, as participants' RTs were shorter when exposed to repeated compared to random configurations; and this difference was evident across both near and far targets. Similarly, a practice effect was also observed as RT decreased as epoch increased.

When examining whether depth influences the cueing effect, our experiment yielded a pattern of result that was contrary to our hypothesis. Participants on average responded faster on trials with targets presented further away than closer. This was surprising for two reasons. First, as objects closer to the viewer would have been larger and more salient compared to targets further away, we expected these objects to grab attention in an involuntary, bottom-up fashion (Pieters & Wedel, 2004; Theeuwes, 2010); hence participants should have been faster in responding to near targets compared to far. Second, studies exploring attentional asymmetry had suggested that across 3D spaces, the peak in attention was directed to the area of space close to the observer (Andersen & Kramer, 1993; Gawryszewski et al., 1987; Miura et al., 2002). Our results suggested that participants' attentional distribution pattern was not consistent with previous research.

Interestingly, Maringelli, McCarthy, Steed, Slater, and Umiltá (2001) found that attentional asymmetry across depth was influenced by a frame of reference. They placed participants in a virtual reality environment and provided half of them with a computer rendered body – the frame of reference, and were told to respond to a target as quickly as possible. They found a significant difference in attentional distribution between the two conditions. Participants who were provided with a body showed an attentional distribution that was similar to Gawryszewski et al. (1987) and Andersen and Kramer (1993), with a strong focus of attention on the near plane. In contrast, participants without a body exhibited an opposite pattern, where the peak of attention was concentrated on the far plane. The results of our experiment agree with the latter and suggest that the bias in attentional allocation across space could override stimulus-driven attentional capture.

We also failed to observe a difference in the magnitude of the cueing effect between near and far targets. If we apply the findings of Maringelli et al. (2001) to modify our initial hypothesis, one would then expect the cueing effect to be larger for near than far targets – as it required the individual to search through and encode objects at both far and near depths to locate a near target. However, that was not the case either. Song and Jiang (2005) suggested there is a limit on the possible target-distractor associations that can be acquired. As the amount of predictive information was equal across both depths, it did not matter whether the viewer first searched, and subsequently learnt, the objects on either the near or far depths – the amount of information learnt would have been the same and equally useful. Thus, we could not identify which distractors were learnt that resulted in the cueing effect as caused by attentional asymmetry.

To sum up, Experiment 1 demonstrated that virtual reality is a platform that can be employed to examine contextual cueing. Despite the failure to observe an increase in the cueing effect as a function of search time (influenced by attentional biases), the results suggest that there potentially was a limit on learning. In conjunction with the effects of different attentional distribution across depth, these could influence on the resulting contextual cueing effect. Though Experiment 1 could not provide conclusive evidences for the above speculations, this was later explored in Experiment 2.

Experiment 2

Experiment 2 aimed to further examine whether the contextual cueing effect was influenced by how attention is distributed across depth. Experiment 1 showed that there wasn't any difference between learning for near and far target associations. As it was suspected that limitations on the possible number of target-distractor associations that can be learnt may also influence the size of the cueing effect and all distractors were predictive of target locations, it is unclear which set of distractors were learnt in Experiment 1. Experiment 2 allowed us to examine this by manipulating allocentric associations of target and repeating distractors via depth-defined short and long-range relationships. Furthermore, as participant's explicit knowledge of the repeating configurations were not tested in Experiment 1, Experiment 2 also included the guessing task as the awareness test.

Past research had discovered evidence that supported the role of both local and global (short and long-range) information in constructing a spatial representation map. Olson and Chun (2002) found that the preservation of local context facilitated search speed. However, their findings were inconclusive, as they also noted that long-range context can improve target localisation, but only when no extraneous information were in between the predictive information and target. The computational model by Brady and Chun (2007) explained these differences by demonstrating how attentional focus tends to begin with a smaller scope, focusing on local information. Depending on the amount of information available within that scope, it could broaden to incorporate global information.

Similarly, two opposing perspectives about attentional deployment across 3D space have been put forward. Early studies using 3D displays observed an asymmetry in attention where a peak was found in regions of spaces closer to the observer (Andersen & Kramer, 1993; Gawryszewski et al., 1987; Miura et al., 2002). However, work by Maringelli et al. (2001) using virtual reality found contrasting results: the peak of attention was deployed in regions of spaces further away from the viewer, a similar result that we also yielded in Experiment 1. They noted that this difference was mediated by a frame of reference. When the observer's body was in full view, attentional focus centered close to the viewer. Whereas when it wasn't available, the peak of attention was located further away from the individual.

In Experiment 2, the two possible kinds of allocentric learning were examined by manipulating the relationship between the subset of repeating information and target across depth. As repeated information within configurations was restricted to only eight out of 16 distractors, we manipulated target-repeated distractor associations through depth-defined short (proximal) and long-range (distal) relationships. Proximal relationship was operationalised as distractor-to-target relationships within the same depth. In contrast, distal relationship referred to distractor-to-target associations that spread across depths. The two kinds of allocentric representation were defined based on these two distinctions. Proximal relationship, henceforth proximal, had the target and predictive information sharing the same depth. Distal relationship on the other hand, henceforth distal, had the target and repeating distractors occupying different depths. Observers were trained on either condition with both near and far targets. Due to the overall reduction of predictive information that is available to be learnt in the experiment, we anticipated that this would result in an overall weaker contextual cueing effect. To maximise the learning effects we would obtain, we therefore increased the ratio of repeated trials to random trials. We achieved this by presenting random trials intermittently throughout the experiment (see below), rather than continually.

Contextual cueing effects could also be compared across participants depending on their egocentric representations of the context. This was achieved by examining the size of the cueing effect between a subset of trials in which repeating distractors were presented either closer or further away from the viewer. This allowed us to examine the combined effects of attentional bias across depth and limitations of learning on the contextual cueing effect. To assess egocentric learning, the data had to be divided up to obtain the subset of trials that had repeating information near or far away from the viewer. This required the extraction of trials across allocentric conditions. For example, the subset of trials with predictive information near to the viewer included trials with near targets under proximal conditions and trials with far targets under distal conditions. Similarly, for the subset of trials with predictive information further away, this included trials with far targets under proximal conditions and trials with near targets under distal conditions. As participants were exposed to either proximal or distal manipulations of allocentric relationships, this meant that within each egocentric representation 'groups' (predictive near and predictive far), target position (near vs. far) was examined as between subjects. Therefore, these two 'groups' cannot be directly compared to one another as participants were neither randomly allocated to either egocentric representation nor were these representations equally examined across all participants as a within subject factor. Instead, the only conceivable comparison that can be conducted is by comparing the cueing effect between near and far targets within groups of trials that consistently had predictive information either closer or further away from the observer.

In considerations of previous research, we hypothesised that: (1) replicating the findings of Experiment 1, configurations with targets further away would have a shorter reaction time than closer targets, (2) extrapolating from the findings of Olson and Chun (2002), if our spatial maps are sensitive to depth-defined spatial regularities, then the contextual cueing effects would be larger in the proximal compared to distal condition. (3) Similarly, the cueing effect would also be strongest when the target was presented further away under the proximal condition if attentional allocation was also biased towards far regions of spaces (Maringelli et al., 2001). (4) No differences in the cueing effect across target position were expected when predictive information was presented closer as learning would've been preoccupied by non-predictive, far objects. (5) Observers should also not demonstrate an explicit awareness of the repeating configurations in the guessing task as previous works had shown that contextual learning was acquired via implicit means.

Method

Participants.

Twenty male and 48 female undergraduate psychology students (*N* = 68; mean age = 19.33, *SD* = 2.33) from University of New South Wales took part in this 1-hour study in exchange for credit points. All other aspects of participant recruitment, exclusions and requirements were the same as Experiment 1a. Participants were randomly assigned to the two between-subject conditions (*n* = 34).

Design, Materials and Procedure.

Experiment 2 used a 2 × (2) × (2) mixed factor design. Allocentric relationships (the distance between target and repeating distractors) acted as the between subject factor and was operationalised to depth-defined proximal and distal relationships. The two levels were proximal (when the target and repeating configuration shared the same depth) and distal (when the target and repeating configurations occupied different depths). The two within subject factors – target position and configuration type and dependent variable – reaction time, were the same as Experiment 1.

In addition, recognition performance was measured as the dependent variable for the guessing task in awareness test (Phase 3). The guessing task required participants to guess where the target would be at for a given configuration. Here, targets were replaced with a distractor and participants were to indicate which distractor had replaced the target by looking directly at the specific distractor and making a response. For the guessing task (see below) we compared the centre of the viewpoint with the target position, calculating the degrees of angle in error of target detection. Larger values of degree of angle in error would suggest poor knowledge of the target position. Similar errors on repeated and random trials would indicate a lack of explicit awareness of contextual configurations and their target locations. Moreover, the positions of the near and far hemispheres were changed to 3 and 6 (see Figure 4), respectively, to accentuate the difference in depth. The design and presentation schedule for Phase 1 was identical to Experiment 1b.

Repeated Proximal vs. Distal Configurations.

To investigate whether depth-defined proximal and distal information (in relation to the target) produces different magnitudes of the cueing effect, the amount of predictive information was halved: of the 16 distractors, eight were repeated for both proximal and distal conditions in Phase 2. In other words, 16 distractors and one target were presented, as per Experiment 1, but only eight distractors were predictive for the repeating configurations.

All six patterns used in Experiment 2 can be summarised as follows (Figure 8):

- Proximal-near: Target and repeating distractors both appeared on the near hemisphere and distractors further away were randomised.
- Proximal-far: Target and repeating distractors both appeared on the far hemisphere and distractors close to the observer were randomised.
- Distal-near: Target was presented close to the participant but with repeating distractors on the far hemisphere.
- Distal-far: Target was presented further away from the participant but distractors on the near hemisphere repeated.
- Random-near: Target was presented close to the participant and all distractors were randomised.
- Random-far: Target was presented further away from the participant and all distractors were randomised.

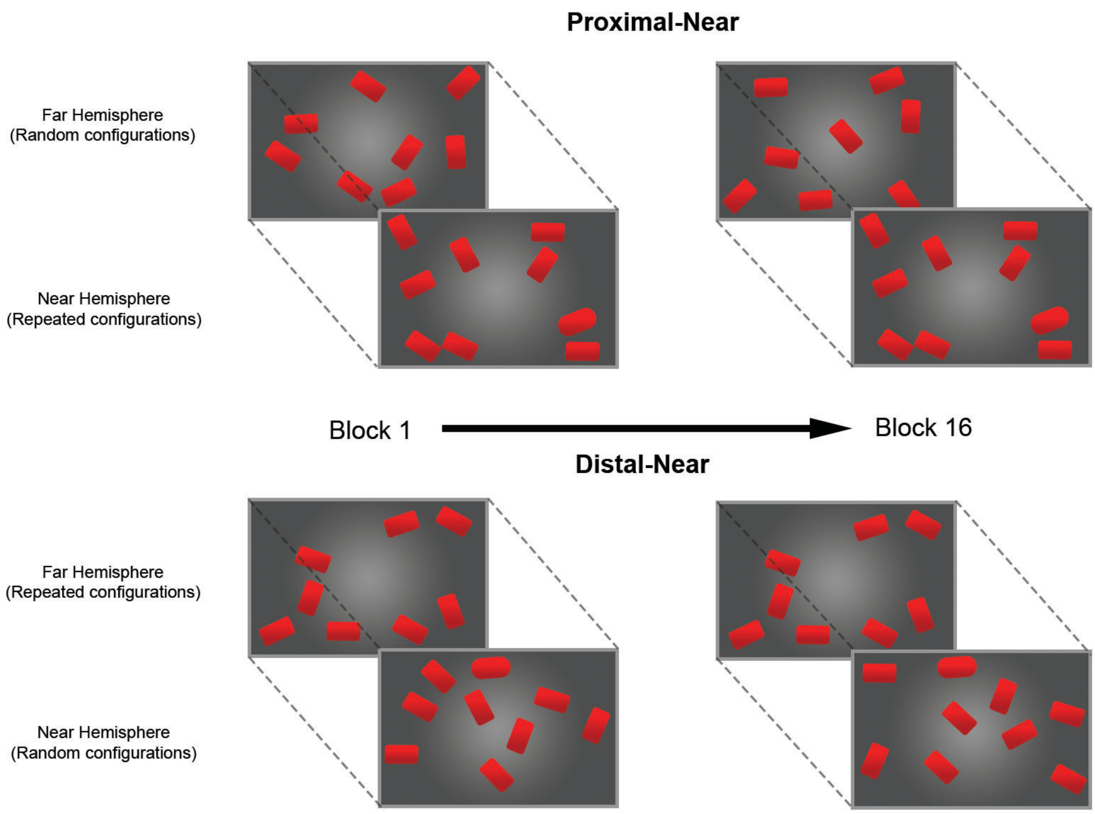

Figure 8: 2D schematic examples of display for conditions Proximal-Near and Distal-Near across blocks. Proximal conditions had the target and repeating information on the same depth hemisphere. In contrast, the target and repeating information were always presented in different hemispheres for the Distal conditions. The other two conditions were similar except with targets on the far hemisphere.

The presentation schedule for Phase 2 was also modified. There was an unequal presentation of repeating and random configurations across the 62 blocks in Experiment 2. For each of the patterns with repeating configurations, four patterns were generated at the beginning of the experiment and presented repeatedly throughout the experiment. These were presented once per block, resulting in eight trials per block and they make up the ‘repeating’ block. A ‘random’ block on the other hand, comprised eight trials of random configurations only (four each with targets near and far). After every 16 consecutive repeating blocks, four random blocks were inserted. This arrangement was repeated three times, with a final period of two repeating blocks at the end of the main task: blocks 1-16, 21-36, 41-56 and 61-62 consisted of repeated configurations; blocks 17-20, 37-40 and 57-60 consisted of random configurations. This resulted in a total of 50 blocks of repeated configurations (400 trials) and 12 blocks of random configurations (96 trials). To prevent fatigue, participants were given a break every four blocks for as long as they required.

Phase 3: Awareness.

The awareness phase employed the guessing task that was used in the studies by Chun and Jiang (2003) and Chua and Chun (2003). Here, two blocks of 16 trials consisting of all four experimental conditions were presented. Two new sets of “novel repeating” configurations were created. These configurations were therefore not familiar to participants but repeated to the same degree as old repeated configurations during the awareness phase. A contrast between performance on old-repeating and novel-repeating provides a measure of participant awareness. Awareness trials differed to those in the practice and experimental phases by replacing the target stimulus with a distractor stimulus. Participants were required to examine the configurations and decide which distractor they thought had replaced the target. Participants made their selection by fixating the distractor and pressing ‘spacebar’.

The awareness phase was presented following the completion of the experimental blocks. Here, participants were made aware about the repeating nature of some of the configurations in the task. They were also informed that in the following trials, configurations will be presented where the target had been replaced by a distractor. Their task was to decide where the target would be for a given configuration and a response was made by directing their head position to fixate on the selected object and pressing ‘spacebar’.

Results

The same exclusion criteria from Experiment 1 was applied to Experiment 2. As a result, two participants each were excluded for making more keypress response compared to others, had more trials with timeouts and slow RTs. Five of the excluded participants belonged to the proximal condition and one from the distal condition. The final number of participants per group was 33 and 29, for the proximal and distal conditions, respectively. Of the remaining 62 participants, 1.13% of all trials combined were discarded from the analysis due to timeouts (0.72% of trials from near-repeated configurations, 1.56% far-repeated, 0.60% near-random and 1.58% far-random).

Contextual Cueing Analysis.

Recall that participants were consistently presented with repeating blocks but only shown four random blocks three times throughout the experiment. The sequential nature of the blocks and the shortening of RTs occurring in this study meant that it's difficult to simply contrast RTs to repeating trials with RTs to random trials. Therefore, to remove any effect of block, the contextual cueing effect was examined only across the blocks where observers experienced an equal amount of both repeated and random configurations. These blocks were defined as test periods. As all data were aggregated to 31 epochs in the analysis, with each epoch representing the averaged RT across two consecutive blocks; each test period compared the average of two random epochs to the average of one of each of the repeating epochs preceding and succeeding the random epochs. Altogether, three test periods were determined across the blocks. They were blocks 8-11, 18-21 and 28-31.

A four-way mixed-model ANOVA was conducted to analyse the contextual cueing effect. Condition (proximal vs. distal) was entered as the between subject factor and test period (1 vs. 2 vs. 3), configuration (repeated vs. random) and target (near vs. far) were the within subject factors. Participants' mean RT across blocks are shown in Figure 9. There was a significant main effect of test period ($F(2, 120) = 61.48$, $p < .001$, $\eta_p^2 = .51$). A test of linear contrast for test period showed that participants' RT decreased as test period increased ($F(1, 60) = 137.02$, $p < .001$, $\eta_p^2 = .70$). Target also showed a significant effect on RT, where RT was shorter when targets were presented further away from the participant ($M = 2079$, $SE = 45.71$) compared to closer ($M = 2541$, $SE = 44.82$), $F(1, 60) = 115.89$, $p < .001$, [-548.37, -376.51]. The interaction of test period and target however, did not reach significance, $F < 1$. The main effect of condition was not significant either $F < 1$, suggesting that speed of target localisation did not differ under proximal and distal conditions. None of the two-way and three-way interactions between test period, target and condition were significant ($ps > .05$).

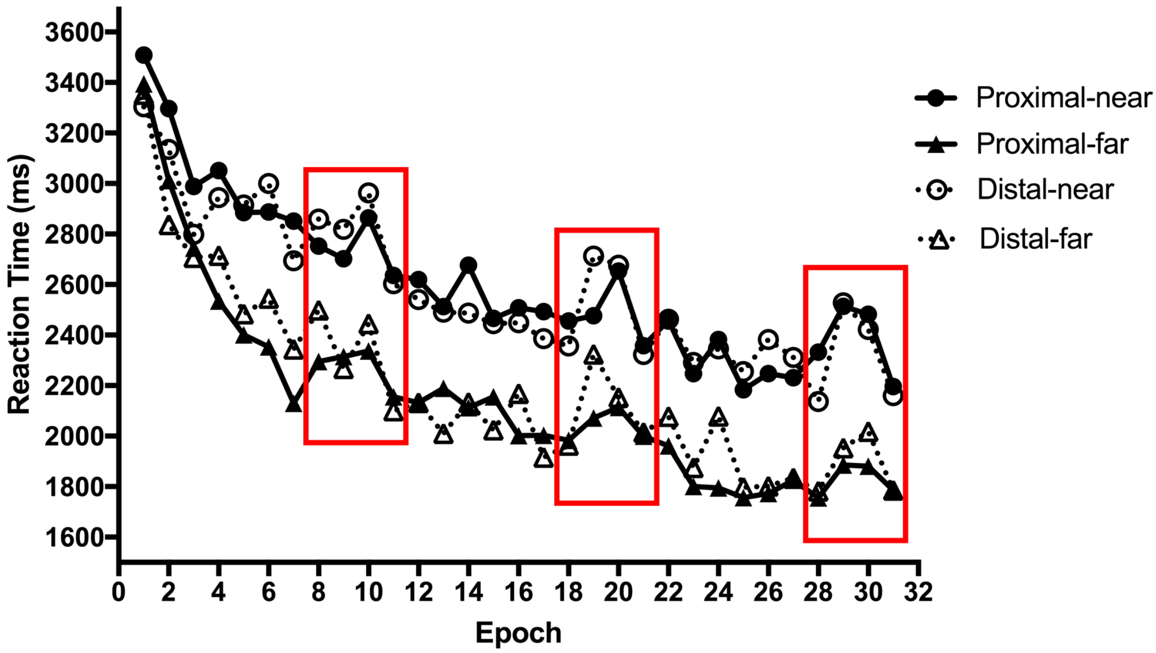

Figure 9: Mean reaction time across block for Proximal-near, Proximal-far, Distal-near and Distal-far conditions. Each epoch represented the averaged reaction times of two consecutive blocks (16 trials). Each test period is highlighted by the borders.

A main effect of configuration was observed ($F(1, 60) = 39.11$, $p < .001$, [-235.73, -121.48]), where RTs were on average faster when participants experienced repeated compared (M = 2220, SE = 42.76) to random (M = 2399, SE = 41.89) configurations. This demonstrated the contextual cueing effect. Non-significant interactive effects between test period and configurations ($F(2, 120) = 2.51$, $p = .086$, $\eta_p^2 = .04$) suggests that there could be a ceiling effect in contextual cueing as the cueing magnitude did not significantly differ as test period increased.

Like the findings of Experiment 1, the Configuration × Target interaction did not reach significance, $F(1, 60) = 2.26$, $p = .138$, $\eta_p^2 = .04$, demonstrating the lack of difference in the contextual cueing effect across near and far targets; despite a significant cueing effect in both near ($t = 5.47$, $p < .001$, [-295.02, -137.11]) and far ($t = 3.39$, $p = .001$, [-214.99, -55.40]) targets (Figure 10a).

The interaction of main interest was the Configuration × Condition and Configuration × Condition × Target interactions. This allowed us to examine whether the two different allocentric coding of invariant information and the target positions produced varying magnitudes of contextual cueing. However, there were no significant effect in both Configuration × Condition ($F(1, 60) = 2.60$, $p = .112$, $\eta_p^2 = .04$) and Configuration × Condition × Target interactions ($F(1, 180) = 0.26$, $p = .616$, $\eta_p^2 = .00$). Follow up t-tests (on repeated vs. random trials for each type of trial) showed a significant cueing effect in all conditions: proximal-near ($t = 3.29$, $p = .002$, [-259.00, -61.03]), proximal-far ($t = 2.15$, $p = .039$, [-204.72, -5.42]), distal-near ($t = 4.47$, $p < .001$, [-408.06, -151.64]) and distal-far ($t = 2.61$, $p = .014$, [-302.63, -36.32]) (Figure 10b). Non-significant interactions indicated the cueing effect did not differ as a function of proximal and distal allocentric coding of predictive contextual information nor across near and far targets. None of the remaining three-way and four-way interactions of test period, target, configuration and condition were significant (ps > .05).

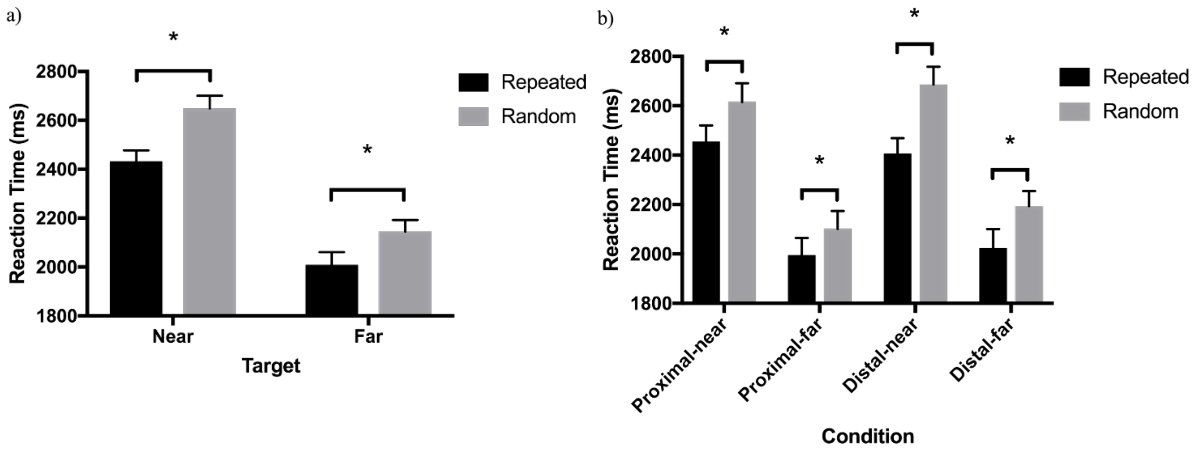

Figure 10: Mean reaction time for repeated and random configurations for a) near and far targets, and b) Proximal-near, Proximal-far, Distal-near and Distal-far conditions. *p < .05, error bars represented the standard error of the mean.

Analysis of Egocentric Learning.

One other outcome of our experimental design is that it also allowed us to extrapolate the results to examine for potential egocentric learning of contexts. Due to constraints with the experimental design, the comparisons of egocentric learning can only be performed across the target factor. To do so, we first separated the data depending on target position. Trials were then re-grouped based on whether the participant consistently received predictive information closer or further away from them. Recall that within each condition (proximal and distal), participants experienced configurations with both near and far targets. In the proximal condition, a near target indicated that participants similarly encountered predictive information in the near hemisphere; whilst a far target would suggest the predictive information was further away. Under the distal condition, a near target implied predictive information was further away and a far target had predictive information closer to the viewer. Therefore, trials in the group with predictive information close to the viewer, henceforth 'P-

Near', consisted of trials from the proximal condition with near targets and trials from the distal condition with far targets. Similarly, trials in the group with predictive information further away from the viewer, henceforth 'P-Far', were made up of trials from the proximal condition with far targets and trials from the distal condition with near targets.

A three-way within subjects ANOVA with test period (1 vs. 2 vs. 3), configuration (repeated vs. random) as within subject factors and target (near vs. far) as the between subject factor was conducted each separately for both P-Near and P-Far.

For P-Near, there was a significant main effect of test period, $F(2, 120) = 31.76$, $p < .001$, $\eta_p^2 = .35$, and a test of linear contrast indicated as test period increased, RT decreased ($F(1, 60) = 62.75$, $p < .001$, $\eta_p^2 = .51$) (Figure 11a). The factors of target and configuration were also significant. Targets further away ($M = 2109$, $SE = 66.46$) had a shorter RT compared to near targets ($M = 2535$, $SE = 62.30$), $F(1, 60) = 21.92$, $p < .001$, [-608.67, -244.26]. Repeated configurations ($M = 2240$, $SE = 49.90$) had shorter RTs compared to random configurations ($M = 2404$, $SE = 49.58$) – exhibiting on overall contextual cueing effect ($F(1, 60) = 16.97$, $p < .001$, [-244.74, -84.75]). Paired sample t-test on the cueing effect across near and far targets indicated a contextual cueing effect was present in both target conditions (near: $t = 3.29$, $p = .002$, [-259.00, -61.03]; far: $t = 2.61$, $p = .014$, [-302.62, -36.32]). None of the two-way and three-way interactions were significant, *ps* > .05.

For P-Far, similar results were obtained. On average, participants were faster on far targets ($M = 2048$, $SE = 61.53$) than near targets ($M = 2547$, $SE = 65.64$), $F(1, 60) = 30.69$, $p < .001$, [-678.39, -318.45]; had shorter RT on repeated ($M = 2201$, $SE = 46.81$) than random ($M = 2394$, $SE = 51.25$) configurations ($F(1, 60) = 24.04$, $p < .001$, [-270.98, -113.94]) and difference in performance over time ($F(2, 120) = 53.87$, $p < .001$, $\eta_p^2 = .47$) (Figure 11b). Linear contrast again suggested an improvement in performance with time, $F(1, 60) = 115.24$, $p < .001$, $\eta_p^2 = .66$. The interaction between Configuration and Target was significant

($F(1, 60) = 4.96$, $p = .030$, $\eta_p^2 = .08$), indicating there was a difference in the size of the contextual cueing effect between near and far targets. Paired sample t-test revealed significant cueing effects in near ($t = 4.47$, $p < .001$, [-408.06, -151.64]) and far targets ($t = 2.15$, $p = .039$, [-204.72, -5.42]). As perceived from Figure 11b, the contextual cueing effect was larger when the target was further away compared to when it was near the observer. All remaining two and three-way interactions were non-significant, *ps* > .05.

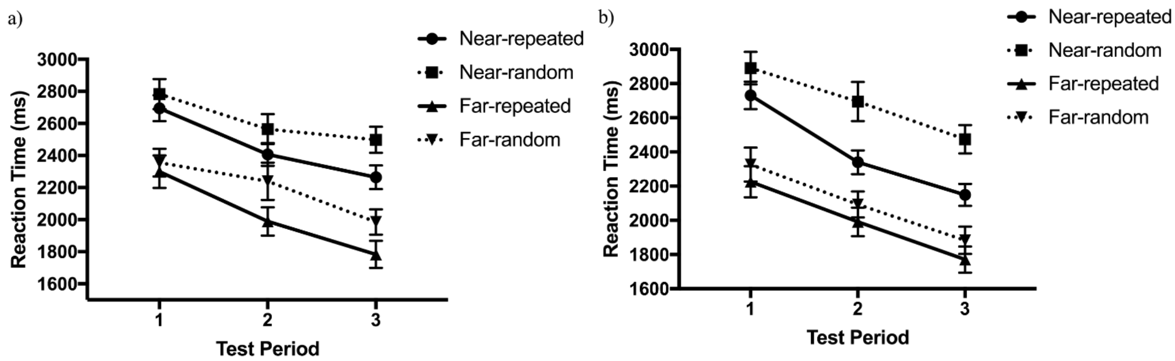

Figure 11: Mean reaction time for repeated and random configurations with near and far targets for group a) P-Near, and b) P-Far. Error bars represented the standard error of the mean.

Awareness performance: Guessing task.

A two-way mixed-model ANOVA was conducted to analyse explicit awareness of the configurations. Configuration (repeated vs. random) was the within subject factor and condition (proximal vs. distal) the between subjects factor. There were no significant difference in angle of error (error distance between the centre of the participant's view point at the time of response and target position) across configuration ($F(1, 60) = 2.70$, $p = .105$, [-3.09, 0.30]), condition ($F(1, 60) = 2.48$, $p = .121$, [-4.59, 0.55]) and no effects of interaction was observed ($F(1, 60) = 0.09$, $p = .772$, $\eta_p^2 = .00$). This indicated participants' guessing of target position were not any more accurate for repeated compared to random configurations.

Correlation of the cueing effect to awareness.

The pattern of participant's mean angle of error across configurations suggests repeated configurations had a lower mean angle of error. Therefore, we decided to assess the correlation between participant's magnitude of contextual cueing (averaged across allocentric conditions and target position) to an awareness score – obtained by subtracting the angle of error for repeated configurations from random configurations. A positive score would indicate that participants were more accurate and aware of the configurations compared to a negative score. There was no significant correlation between these two variables, $r = .167$, $n = 62$, $p = .194$.

Discussion

The objectives of Experiment 2 were to investigate the effects of attentional asymmetry across depth on the contextual cueing effect. The number of predictive information was halved and its allocentric relationship to the target position were manipulated based on depth-defined proximal and distal relationships. First, our results replicated the findings of Experiment 1a & 1b, where participants on average were faster to locate the target when it is presented further away than closer. This once again demonstrated that there appears to be an attentional bias towards far regions of spaces.

Second, we hypothesised that a larger cueing effect would be observed in proximal than distal condition, and this effect would be strongest when both target and repeating distractors were presented further away. Our initial hypothesis was derived from works on the learning of 2D short and long-range contexts, where an attentional spotlight restricted learning to associations that were arranged closer in space (Brady & Chun, 2007; Olson & Chun, 2002). This notion was extrapolated to depth-defined spatial regularities. Regardless of unequal distribution of attention across space, if our spatial maps are "depth aware", we expect that proximal conditions (depth-defined short-range contexts) would result in a stronger cueing effect. Evidently, in contrast to our hypothesis, there was no difference in the cueing effect between the two allocentric learning conditions. This could be due to the differences in our definitions of short and long-range contexts to 2D works. For our hypothesis to have the desired results, a huge assumption was made: depth is represented in our spatial maps. If, instead of manipulating the relationship between predictive information and the target location across depth-defined proximal and distal relationships; predictive information was held constant relative to only their 2D spatial distance to the target regardless of depth, it could be possible we would've observed a stronger contextual cueing effect when proximal target-repeating distractor associations are repeated. This representation however, would not have given much insight to as whether depth information was learnt. From a simplified point of view, our results from the manipulations of allocentric representations may suggest that depth-defined spatial regularities are not encoded. But that may not entirely true as this ignored the influences of attentional asymmetry. Jiang, Swallow & Capistrano (2013) suggested that different attentional modes may affect the type of spatial representational system involved. For instance, they found that incidental learning, such as probabilistic cueing, was egocentric. To more appropriately examine whether unequal attentional distribution and depth-defined spatial regularities affect the contextual cueing effect, the learning of egocentric representations of contexts were examined.

For egocentric learning, the findings for trials in group P-Near were in-line with our hypothesis. No significant differences in the cueing effect were found between near and far targets when predictive information was always presented closer to the participant. Surprisingly, trials in group P-Far revealed a significant difference in the cueing effect across target positions. The contextual cueing effect was found to be stronger when predictive information was shown further away alongside a far target. As there are limitations on the amount of associations that can be learnt (Song & Jiang, 2005), the prioritisation of far regions seemed to influence what information are first encountered and learnt, and this subsequently affects the magnitude of the contextual cueing effect. From an egocentric point of view, when predictive information is presented further away from the viewer, learning of proximal target-repeated distractor associations are stronger than distal. Alternatively, when predictive information was closer to the participant, in other words, non-predictive information was first experienced and learnt; it does not matter whether the target was on the same or different depth relative to the repeating information – learnt associations were not useful. Nonetheless, attentional spotlight may come to expand (Brady & Chun, 2007) and distal relationships could be acquired through latent learning (Jiang & Leung, 2005), thus cueing effects were still observed in configurations with predictive information closer to the viewer.

Finally, in agreement with the previous works of the contextual cueing effect, participants showed no explicit recognition of the repeating configurations. Though there were no significant differences between participants' mean degree of angle of error for repeated compared to random configurations in the awareness phase, comparisons of the descriptive means suggested that angles of error were on average lower for repeating configurations. However, a non-significant correlation between magnitude of the cueing effect and awareness further indicated there was no relationship between the two factors. This suggests that contextual learning was acquired via implicit learning.

General Discussion

The overarching aim of the present study was to investigate whether depth-defined spatial regularities were encoded as part of our spatial representations of contexts. Early 3D works on depth encoding in the contextual cueing effect had yielded contrasting results, leaving the on-going debate unresolved. Attentional distribution was a key component in 2D studies of contextual cueing that was overlooked when it came to 3D studies. Specifically, how attention could peak at regions of spaces near (Andersen & Kramer, 1993; Gawryszewski et al., 1987; Miura et al., 2002) or far away (Maringelli et al., 2001) from the viewer depending on the availability of a frame of reference. Here, in a series of three experiments, we demonstrated that attentional asymmetry across depth plays an influential role in determining what information are learnt, how this affects the magnitude of the cueing effect and that our spatial maps are sensitive to depth-defined spatial regularities.

Summary

Contextual Cueing Effect in Virtual Reality.

As virtual reality is a novel platform to conduct the contextual cueing paradigm, one of the key objectives of this study was to validate the procedure. This was achieved by successfully establishing a robust contextual cueing effect across all three experiments. The first set of experiments (Experiment 1a & 1b) also aimed to investigate whether the cueing effect is affected by an attentional asymmetry across depth. Attentional asymmetry effects were observed, where reaction times were shorter for far compared to near targets. However, we failed to find a significant difference in the size of the cueing effect between near and far targets as a result of longer search time (Chun & Jiang, 1998; Zhao et al., 2012) influenced by attentional biases. As there is a limitation on the number of information within a context that can be learnt (Song & Jiang, 2005), it was suspected that the lack of difference in the magnitude of the cueing effect may be a result of such constraint. As predictive information was equally distributed across the two depths in Experiment 1, differences in the cueing effect due to attentional biases and limited learning could not be observed as the amount of learning of predictive information across depth would've been equal for near and far targets.

Attentional Bias and Depth-Defined Spatial Relationships on The Cueing Effect.

Presentations of predictive information was reduced in Experiment 2 to examine the effect of attentional bias on the cueing effect. Two allocentric conditions (proximal and distal) were defined based on depth-defined proximal and distal relationships of target and repeating distractors. No differences were found in the magnitude of the contextual cueing effect between allocentric conditions. This was despite previous works suggesting predictive short-range contexts are first learnt and better contributors to the cueing effect than long-range contexts (Brady & Chun, 2007; Olson & Chun, 2002). Nevertheless, a more interesting perspective was offered when the data was reorgniased based on egocentric representations of the relationship between predictive information and the observer. A significantly larger cueing effect was discovered when both repeating distractors and the target were presented further away compared to a near target with far repeating distractors. In contrast, no differences in the cueing effect were found across both target locations with a predictive information near to the participant. This suggests an important interplay between attentional asymmetry, limited learning and depth-defined spatial relationships of target and distractors in determining the contextual cueing effect.

Implications of current studies

Role of Attentional Guidance in Contextual Learning.

One of the most recognised mechanism involved in the acquisition of the contextual cueing effect is attentional guidance. Whereby past experiences with regularities in the visual context (Zhao, Al-Aidroos, & Turk-Browne, 2013) serves to guide attention that facilitates the learning of predictive information (Chun, 2000) and inhibits attentional allocation to non-predictive information (Ogawa, Takeda, & Kumada, 2007). This notion is similarly echoed in works of local and global contexts (Brady & Chun, 2007; Olson & Chun, 2002), selective attention (Conci & Mühlenen, 2009; Conci et al., 2013; Jiang & Chun, 2001; Jiang & Leung, 2005; Kawahara, 2003) and eye tracking studies (Asselen, Sampaio, Pina, & Castelo-Branco, 2010; Brockmole & Henderson, 2006; Peterson & Kramer, 2001; Zhao et al., 2012). Furthermore, the contextual cueing effect could influence the exercise of both top-down and bottom-up attentional modes to suppress abrupt but detrimental onsets of distractors during search (Peterson & Kramer, 2001).

This consensus however, is not always agreed upon. Questions were raised regarding the contradicting implication of attention and automaticity of implicit learning. Earlier studies have found the role of attention in implicit learning to be inconsistent, where depending on the task, certain implicit processes may require attention (Tipper & Cranston, 1985) and some not (Nissen & Bullemer, 1987; Turk-Browne, Jungé, & Scholl, 2005). Rausei, Makovski, and Jiang (2007) manipulated the observer's dwell time on distractors, by presenting highly similar or dissimilar distractors to the target, found that the magnitude of the contextual cueing effect between the two types of distractors were comparable. This indicates that despite highly similar distractors would result in an increase in attention and dwell time, this did not consequently result in an enhanced learning and a larger cueing effect. Furthermore, as attentional guidance requires time to develop, the usual short RTs observed in cueing paradigms are an unlikely timeframe for guidance to take place (Kunar, Flusberg, & Wolfe, 2008).

When exploring the role of attention in the contextual cueing effect, it is important to distinguish between the directions of effect in which one's tests are examining. Taking into considerations the bi-directionality of learning and attention, the previously mentioned studies majorly focused on the influences of attention on learning. Nonetheless, when the opposite is examined, Kunar, Flusberg, Horowitz, and Wolfe (2007) found interesting evidences for the role of the contextual cueing effect in mediating subsequent response selection more so than attentional deployment. In their study, they first noted a lack of typical decrease in reaction time as set size increased. Second, when a target is strong enough to garner attention on its own, such as in feature searches, this should render the cueing effect redundant if its sole purpose were to guide attention. In other words, a cueing effect should not have been observed, but this was not the case in their experiment as a small contextual cueing effect was present. Keeping in mind the contextual cueing effect was operationalised to be the difference in RT between repeated and random configurations, response is an important factor to investigate to properly isolate the sources of facilitation. Kunar et al. (2008) manipulated the congruency between targets and distractors in a feature search. For example, congruent configurations had a red target A embedded amongst green distractor As, whereas incongruent configurations had a red target A hidden amongst green Rs. They found that the cueing effect was abolished in incongruent configurations, where an interference was introduced to the response selection stage. Together, these indicated that the response selection may account for a larger influence on the contextual cueing effect than attentional guidance.

Having said that, inferences drawn from our study could only suggest evidences for how attention effects learning. Our results indicated that attention played a significant role in the acquisition of the contextual cueing effect. We demonstrated a selective attentional effect that was not due to top-down nor bottom-up manipulations but a result of an asymmetrical attentional allocation across depth. Across all three experiments, our participants were consistently faster at locating a target presented in the far hemisphere than a near target across both repeating and random configurations. And this pattern of behavior was evident despite near objects were larger and salient, and by means more attention grabbing (Pieters & Wedel, 2004). This demonstrates that biases in spatial attention, regulated through a frame of reference, can override salience and bottom-up attentional capture of stimuli. The lack of a 'body' as a frame of reference (Andersen & Kramer, 1993; Gawryszewski et al., 1987;

Maringelli et al., 2001) in our study may have shifted the type of spatial reference frame from viewer-centered to either object- or environment-centered (Farah, Brunn, Wong, Wallace, & Carpenter, 1990), which resulted in the peak of attention being focused on regions further away from the participant, instead of closer. Our egocentric data showed that the cueing effect was stronger when both predictive information and target were presented further away compared to when predictive information was far but with a near target. In contrast, no difference in the cueing effect was observed for near repeating information paired with near or far targets. This suggests that depth-defined proximal relationships were better learnt than distal (only when predictive information was far away) and this was a result of attentional biases.

Prioritisation of Learning on The Cueing Effect.

The results of our egocentric data (Experiment 2) revealed two findings: (1) When predictive information was presented closer to the viewer, there was no significant differences in the size of the contextual cueing effect between near and far targets, and (2) the contextual cueing effect was larger when both predictive information and the target appeared far away than when it was paired with a near target. We interpreted this finding to be due to the interactive effects of bias in attention to far regions of space and a limitation on the possible learning of paired associations (Song & Jiang, 2005). As such, learning is maximised when predictive information is encountered before non-predictive information (Jungé et al., 2007). Similar to the learning of 2D stimuli (Brady & Chun, 2007; Olson & Chun, 2002), objects arranged closer with regards to depth-defined spatial relationships are better learnt. Latent learning of previously unlearned information was also possible (Jiang & Leung, 2005), therefore contextual cueing effects were also observed when predictive information was close to the viewer.

Similarly, the idea of how attention modulates the prioritisation of information to be learnt, and how this subsequently affects the contextual cueing effect, was demonstrated by Conci and Mühlenen (2009). They showed that incidental yet salient region segmentation, such as presentations of grouping operations (e.g., a square) as part of the layout, abolished the benefits of contextual cueing. As there are limitations on the number of target-distractor associations that can be learnt, grouping operations interfere with learning by drawing our attention towards it. Thus, any construction of spatial representations will centre around the relationship between the specific region and the target. Conci and Mühlenen (2009) argued that this representation is therefore less informative during search, as the need to look for three or four objects aligning coincidentally in a particular form is harder than looking for one or two objects in a particular location relative to the target. In other words, selective attention towards perceptual groupings reduced the learning of effective information to drive contextual cueing. A more recent study however, observed no disruptions to contextual cueing when the target was enclosed within the segmented region (Conci, Müller, & Mühlenen, 2013). This poses a problem for the previous explanation by Conci and Mühlenen (2009), as it failed to explain the two opposing patterns of results. Thus, Conci et al. (2013) proposed that in this case, a contextual cueing effect was established through an object-based selection – where more reliable associations were learnt within the segmented region. Perceptual groupings itself formed a constrained environment via selective attention by defining regions of interest and spatial regularities within this region were extracted. Targets and contextual information that lay beyond this constrained environment were not learnt, and thus a contextual cueing effect was not observed. To put it simply, focused attention, towards grouped objects, are not necessarily detrimental in the learning of target-distractor associations. Instead, it can restrict the amount and types of information available to be learnt, and this determines the contextual cueing effect.

The notion of how, depending on what associations are first encountered and learnt, influences the magnitude of learning is also echoed in the blocking effect (Kamin, 1969). In the blocking effect procedure, when participants have learnt that one stimulus perfectly predicts an outcome, i.e., A → X; the introduction of a compound stimulus (AB) leading to the same outcome (X) sees a lack of learning of the secondary stimulus (B). Stimulus B was regarded as redundant as A is a good predictor of outcome X and therefore the learning of B → X was blocked. Whilst not the exact same procedure was used, this effect can be loosely seen in the egocentric data. Whereby an attentional bias to far regions of space first prioritises the learning of object relations in the far hemispheres, target-repeating distractor associations that shared the same depth were better learnt than those that did not. However, in the cases of incidental learning like the contextual cueing effect, blocking effect was found to be weaker (Jones, Gray, & Hemsley, 1990). Therefore, cueing effects were also observed in the subset of trials P-Near. As for P-Near, distractors further away were always non-predictive and first learnt, therefore experiencing the target before or with predictive distractors does not make a difference in the cueing effect. Though our study could not provide evidences directly comparing the size of the cueing effect between trials of P-Near and P-Far, future studies could examine the difference in learning as caused by attentional bias on egocentric representations of the context.

Parallel Representational System in Contextual Learning.

One major unresolved argument raised by 3D studies was regarding the stance of whether our spatial maps are sensitive to depth-defined spatial regularities. Earliest study examining the role of depth information in contextual learning by Kawahara (2003) suggested that target-distractor associations can be formed across depth and this learning can promote a cueing effect. Evidence for the encoding of depth information was demonstrated through disruptions to learnt depth-defined associations, by reversing the distractors on the front and back planes during the test phase, and the contextual cueing effect observed during the learning phase was abolished. This finding however, was recently challenged by Zang et al. (2017). As Kawahara (2003) only reversed distractor positions, but not the target position, across depth planes, it was suspected there was a confound in Kawahara's (2003) study. Importantly, it did not take into considerations of the additional disruption of local allocentric target-distractor associations that sustains the cueing effect when reversing the two depth planes. To address this, Zang et al. (2017) replicated Kawahara's experiment except that local associations were preserved whilst reversing the two depth planes, i.e., both target and distractor locations were reversed across depth. When local associations within a depth plane were not affected, an overall disruption to the 3D layout did not have an impact on the cueing effect. Thus, their results indicated that depth information were not encoded as part of our spatial maps.

A different perspective was undertaken to examine whether depth information was encoded as part of our spatial representation of contexts. This was achieved through investigating the kinds of spatial coding, allo- or egocentric, that is used to learn the associations between repeated distractors and the target position. Previous research has shown that learnt 3D contextual representations are viewpoint dependent (Chua & Chun, 2003; Papenmeier & Huff, 2014), suggesting that the cueing effect was a result of the learning of egocentric associations between the viewer and objects. However, evidences for the involvement of both allo- and egocentric representational systems in contextual learning were later discovered (Tsuchiai et al., 2012). Instead of rotating the context to depict differing perspective of the same image, when participants were instructed to physically move to encode the context from a different perspective, the results were mixed. First, when participants were trained on one perspective of the context and then moved during test, cueing effects were observed. This suggests that target-distractor associations were coded through an allocentric representational system. But, when both the participant moved and the context rotated to create an identical retinal image at both perspectives, contextual cueing effects were also evident. This indicates the employment of an egocentric system that is capable of encoding and updating contextual knowledge via self-motion. The implication of an egocentric coding system in the contextual cueing effect would suggest depth information was encoded, as egocentric representations involved the learning of self-to-object relationships and are 3D.

The notion of two systems working in tandem was similarly considered by Maringelli et al. (2001). They proposed that the observed biases in attentional allocation may be a result of a parallel representational system of two independent attentional systems. When objects appear closer to us, an egocentric representational system is preferred and attention is organised by a system that processes near regions of space. Thus, a frame of reference would facilitate egocentric coding. When objects are far from reach and away from us, the environment is encoded via an allocentric representational system and attention is guided by a different system. A similar pattern of results was also demonstrated in our Experiment 2. Given that there is a limit on target-distractor associations that can be learnt, objects of interest to the observers were the distractors that repeated throughout the experiment. We did not find a difference in the contextual cueing effect between near and far targets when predictive information appeared closer to the viewer. Though this cannot indicate whether an egocentric coding process was undertaken, this may suggest, at the very least, allocentric spatial coding was not in use as the learning of proximal target-repeating distractor associations were not stronger than distal associations. Conversely, when predictive information was in the far hemisphere, depth-defined proximal target-repeated distractor relationships were better learnt, evidenced in a stronger cueing effect, than distal relationships, as seen in 2D studies (Olson & Chun, 2002). This shows that allocenrtic representational systems were employed when encoding predictive configurations from far and this system was sensitive to depth-defined spatial regularities.

Methodological Limitations

As aforementioned, one of the biggest limitations with the design of our study was that it could not directly assess the magnitude of contextual cueing effects across the two egocentric relationships between the viewer and repeating information. Future research should aim at examining this difference to delineate the roles of the two spatial coding systems on contextual learning across depth. This could also further provide evidences for the implication of attentional asymmetry on the contextual cueing effect depending on the egocentric representations of predictive information and the target, and the encoding of depth information.

Implicit Test.

Despite the results of our awareness test suggested participants had no explicit awareness of the repeating configurations, the statistical sensitivity of awareness tests in overall was questioned in the literature. Vadillo, Konstantinidis, and Shanks (2016) recently critiqued on the design of awareness tests and the appropriateness of statistical analysis methodology used to evaluate the nature of contextual knowledge. They pointed out that the literature on the contextual cueing effect had overly relied on null results from awareness tests to demonstrate that cueing effects were acquired implicitly. The authors suggested using a Bayesian approach would allow researchers to quantify whether the null result represented an absence of effect or a lack of sensitivity to examine the intended construct. Being able to appropriately express and test the key knowledge – learnt target-distractor associations, is critical in constructing an effective awareness test, and that was what the guessing task aimed to achieve compared to the recognition task. Another potential improvement is to combine a standard trial with a recognition task and have two stages for every awareness test trial. Stage one mimics the experimental phase, where participants search for the target as quickly as possible. This could then be followed by a second stage, whereby the recognition task directly probes the participant explicit knowledge about the configurations. This way, if participants continue to show a consistently shorter RT to repeated but not random configurations, and their recognition performance falls below chance level; it would provide a more compelling evidence to as the learning of spatial regularities is indeed an implicit learning process.

Conclusion

The aim of this study was to examine the influences of attentional asymmetry across depth on the learning of depth-defined spatial regularities in a contextual cueing paradigm. Over a series of three experiments, we were successful in establishing a robust contextual cueing effect in virtual reality with 3D stimuli and an attentional bias to far regions of space.

To explore whether depth-defined spatial regularities were learnt and encoded in our spatial maps, allo- and egocentric learning of the context were compared. Magnitudes of the cueing effect did not differ across near and far targets nor across the two kinds of depth-defined allocentric relationships between distractors and targets. Though this may suggest depth information was not encoded, reorganised egocentric results suggested otherwise. A stronger cueing effect was observed when both the target and distractor appeared further away compared to a near target with predictive distractors further away. No differences in the cueing effect however were present between near and far targets with predictive information closer to the viewer. This indicates first, there is an interplay between attentional asymmetry and limitations of learning on the cueing effect. Attentional biases to far regions of space resulted in a stronger learning of target-repeating distractors relations further away and subsequently, a larger cueing effect. Second, the contextual cueing effect was sensitive to depth-defined spatial regularities.

Our results also provided preliminary evidences for a parallel representational system across depths. When predictive information was presented further away, depth-sensitive allocentric representations were employed and proximal associations were better learnt than distal. This distinction was not observed when predictive information was displayed closer to the viewer. Thus, at the very least, indicates an allocentric representational system was not in use during the learning near information. Further research is required to uncover whether an egocentric representational system was employed in learning near information.

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[1] Unity units is the Unity engine's scale and can be calibrated to any scale depending on the project. For example, 1 Unity unit = 1 km or 1 cm. For this experiment, Unity units were not calibrated.

[2] Specific dimensions of stimuli with regards to depth, that participants saw through the headset can't be described for two reasons. (1) The Unity engine models its environment to reflect the real world and objects with identical dimensions are perceived to be smaller with distance. Precise measurements of these objects in relation to the viewer's perspective however, cannot be calculated. (2) As all stimuli undergo a transformation through the lenses in the headset, sizes of stimulus may vary depending on the participant's head movements. Nonetheless, relative sizes of stimulus across depth were preserved with movement.

Appendix A: Hemisphere Corrections and Restriction

The input data was created on MATLAB and it places each stimulus on a 12 x 12 grid (from x = 1 to 12, and y = 1 to 12). However, as the Unity program places the camera (the viewer) at centre position (x,y) = (0,0), all objects would be located between (x,y) = (1,1) and (x,y) = (12,12), i.e., all at the top-right corner of the screen. Therefore, to spread all the objects out across the screen, corrections were made to the input data. These corrections are as follows:

- x = input_x - 6.0;
- y = input_y - 6.0 / 2.0;

This gave the bounds as follows:

- -6 Unity units <= x <= 6 Unity units – this stopped the objects from appearing too far to the left or right of the viewer
- -3 Unity units <= y <= 3 Unity units – this stopped the objects from appearing too far above or below the viewer

There were also restrictions on the depth radius r >= 2 Unity units, stopping objects from appearing too close to the viewer.

Appendix B: Detection Mechanism

An invisible ray was projected from the middle of the participant's visual field, known as 'look line', to indicate where the participant was directly looking at. A cross product between the vectors of the target and look line gave the smallest distance between the target and the look line, and this value is known as the error (i.e., how far away from the target are you looking, measured in distance values). This method of calculating error was later found to be problematic. This was because the error value changes depending on depth. In a situation where the degrees of angle of distance off the target is the same (where the look line is at compared to actual target position) for two different depth hemispheres, their error differed. In particular, error was inflated with increasing depth.

Experiment 1a employed a detection method called 'spherecasting'. A sphere with a fixed radius of 0.8 Unity units was centred around the look line. If the sphere at any point overlaps with the target, then the target is 'detected'. In other words, the target had to be within 0.8 Unity units of the look line (error < 0.8 Unity units), regardless of depth. Recall that the calculation method inflates error when depth is increased, this meant that objects further away were harder to 'detect' compared to those closer to the viewer.

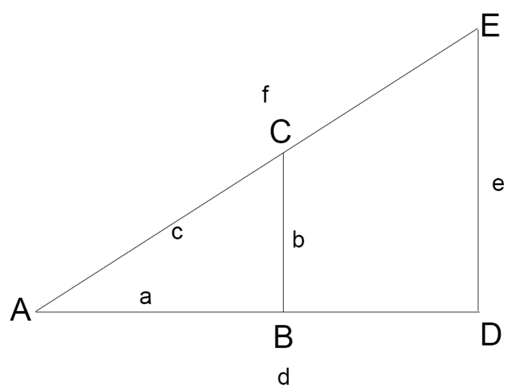


Figure A1: Similar triangles.

Experiment 1b addressed this issue by using a standardised error measurement. This was defined using the concept of similar triangles. For example, in Figure A1, A is the camera, E is the target, and D is the closest point on the look line to the target. With similar triangles, we know that c/f = a/d = b/e. The standardised error measurement was defined with reference to a target at a depth of 7.0 Unity units (RADIUS_7) from the camera (C on the image, and c = 7.0). And the maximum error distance between the target (C) and the closest point on the look line (B) is MAX_DIST_AT_RADIUS_7 (i.e. b = MAX_DIST_AT_RADIUS_7). As b/e = c/f due to similar triangles:

$$\frac{MAX\_DIST\_AT\_RADIUS\_7}{ERROR\_DIST\_AT\_NEW\_RADIUS} = \frac{7}{NEW\_RADIUS};$$

Rearranging gives:

$$ERROR\_DIST\_AT\_NEW\_RADIUS = \frac{NEW\_RADIUS \times MAX\_DIST\_AT\_RADIUS\_7}{7};$$

By doing so, we ensured that:

$$ERROR\_DIST\_AT\_NEW\_RADIUS < \frac{NEW\_RADIUS \times MAX\_DIST\_AT\_RADIUS\_7}{7};$$

The program also pre-sets MAX_DIST_AT_RADIUS_7 = 0.6 Unity units.

Therefore, for every keypress response in a trial, the program:

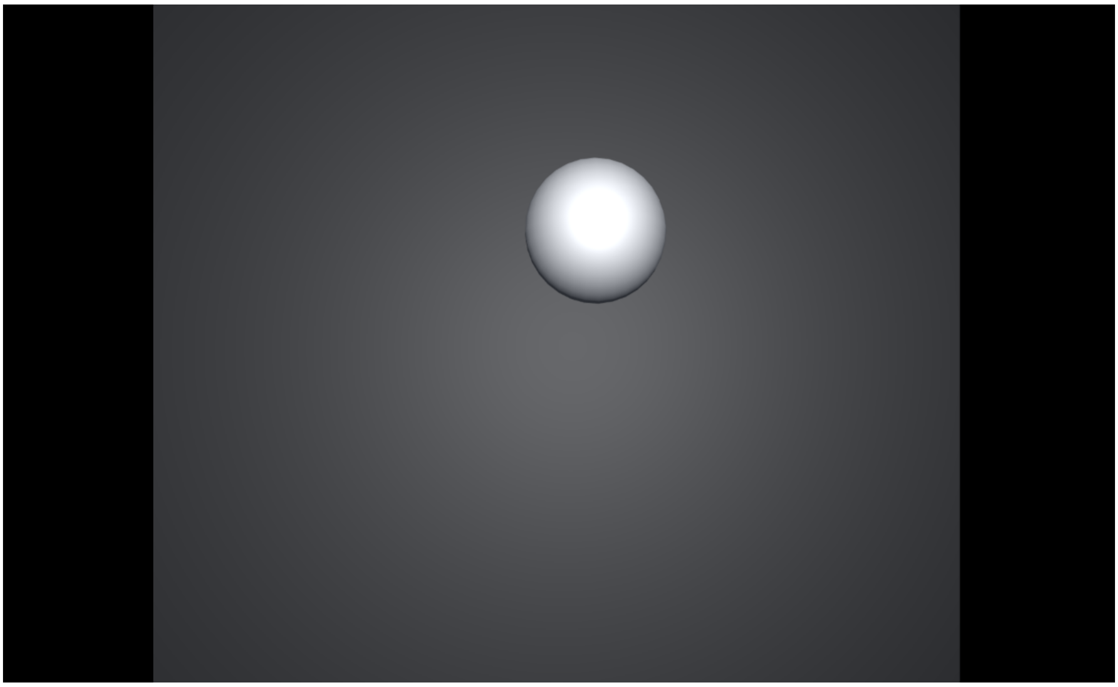
1. Calculates how many Unity units between the look line and the target (i.e. the error distance).
2. Checks to see if:

$$ERROR\_DIST\_AT\_NEW\_RADIUS < \frac{NEW\_TARGET\_RADIUS \times 0.6}{7};$$

3. If true, a detection response occurs.

Appendix C: Screenshot of Fixation Sphere

Screenshot of fixation sphere that appeared in between trials to re-centre participant's fixation.



Appendix D: SPSS Output for Experiment 1a & 1b

Four-way mixed-model ANOVA

Within-subject Factors:

- Epoch: 1 – 10
- Config: Repeated vs. Random
- Target: Near vs. Far

Between-subject Factor:

- Experiment: 1a vs. 1b

Dependent Variable:

- Reaction Time

Descriptive Statistics

	Experiment	Mean	Std. Deviation	N
NearRep1	1a	3208.8792	693.93260	20
	1b	3223.2751	689.79712	18
	Total	3215.6984	682.60651	38
FarRep1	1a	3063.7948	660.26573	20
	1b	3150.0524	884.29134	18
	Total	3104.6537	764.88939	38
NearRand1	1a	3256.4405	748.35584	20
	1b	3267.1758	706.40074	18
	Total	3261.5256	718.94853	38
FarRand1	1a	3103.9674	630.59322	20
	1b	3077.8969	835.19173	18
	Total	3091.6182	724.47588	38
NearRep2	1a	2820.7727	624.14485	20
	1b	3058.6806	712.84040	18
	Total	2933.4659	669.33196	38
FarRep2	1a	2763.4931	682.92475	20
	1b	2797.8363	977.60699	18
	Total	2779.7609	823.96002	38
NearRand2	1a	2963.7072	606.42011	20
	1b	3053.4036	608.00001	18
	Total	3006.1950	600.62287	38

FarRand2	1a	3066.4984	783.41606	20
	1b	2867.2302	652.74717	18
	Total	2972.1082	721.87057	38
NearRep3	1a	2686.7981	615.69379	20
	1b	2939.6549	594.17402	18
	Total	2806.5724	610.93503	38
FarRep3	1a	2517.9977	668.09312	20
	1b	2416.7311	669.31688	18
	Total	2470.0293	661.56078	38
NearRand3	1a	2746.6333	538.17742	20
	1b	3068.5332	686.73245	18
	Total	2899.1122	626.05473	38
FarRand3	1a	2628.2163	854.77126	20
	1b	2593.0046	494.78911	18
	Total	2611.5371	698.56352	38
NearRep4	1a	2822.3970	798.38239	20
	1b	2663.5408	752.89253	18
	Total	2747.1493	770.86030	38
FarRep4	1a	2275.9629	474.79467	20
	1b	2261.7340	643.40858	18
	Total	2269.2229	553.18869	38
NearRand4	1a	2809.3042	577.54710	20
	1b	2877.6473	690.75391	18
	Total	2841.6772	625.86801	38
FarRand4	1a	2641.0577	679.29014	20
	1b	2515.2117	663.08546	18
	Total	2581.4465	665.60079	38
NearRep5	1a	2517.9750	670.21682	20
	1b	2468.0059	734.54181	18
	Total	2494.3054	692.24770	38
FarRep5	1a	2147.5625	399.48770	20
	1b	2078.3241	722.29844	18
	Total	2114.7654	568.23078	38
NearRand5	1a	2668.5235	647.97533	20
	1b	2735.7963	568.78813	18
	Total	2700.3896	604.49402	38
FarRand5	1a	2367.5917	645.44029	20
	1b	2295.7083	706.70121	18
	Total	2333.5417	666.86995	38
NearRep6	1a	2582.0208	673.80825	20
	1b	2580.8519	681.30973	18

	Total	2581.4671	668.14501	38
FarRep6	1a	2213.5083	514.93693	20
	1b	2038.9352	626.73472	18
	Total	2130.8158	569.59677	38
NearRand6	1a	2760.3155	742.48380	20
	1b	2761.6204	642.99037	18
	Total	2760.9336	687.78533	38
FarRand6	1a	2464.8223	714.31505	20
	1b	2389.3859	876.41784	18
	Total	2429.0893	785.10500	38
NearRep7	1a	2458.6625	684.96963	20
	1b	2492.3750	510.91486	18
	Total	2474.6316	600.96385	38
FarRep7	1a	2057.3977	490.34286	20
	1b	2063.0833	528.11364	18
	Total	2060.0909	501.61795	38
NearRand7	1a	2574.1773	670.50018	20
	1b	2709.1898	598.96511	18
	Total	2638.1306	632.74254	38
FarRand7	1a	2121.6591	557.89130	20
	1b	2257.6296	604.16781	18
	Total	2186.0662	576.43075	38
NearRep8	1a	2380.4042	619.59197	20
	1b	2459.5463	568.39055	18
	Total	2417.8925	589.21572	38
FarRep8	1a	1908.1095	384.54442	20
	1b	1893.5316	643.98658	18
	Total	1901.2041	516.27159	38
NearRand8	1a	2420.1303	491.87610	20
	1b	2503.4306	430.99277	18
	Total	2459.5883	459.74341	38
FarRand8	1a	2363.3284	617.89733	20
	1b	2237.2315	585.50150	18
	Total	2303.5983	598.02795	38
NearRep9	1a	2290.4076	526.06944	20
	1b	2361.8796	433.17065	18
	Total	2324.2628	479.20125	38
FarRep9	1a	1974.5640	465.03286	20
	1b	1786.2677	451.79102	18
	Total	1885.3710	462.50514	38
NearRand9	1a	2478.5500	439.23974	20

	1b	2467.1111	399.04862	18
	Total	2473.1316	415.05505	38
FarRand9	1a	2257.2667	669.44794	20
	1b	2159.4377	531.63937	18
	Total	2210.9266	602.03721	38
NearRep10	1a	2182.8250	454.87121	20
	1b	2262.5231	476.84293	18
	Total	2220.5768	460.81214	38
FarRep10	1a	1856.0595	296.51153	20
	1b	1826.7774	595.33356	18
	Total	1842.1890	456.30006	38
NearRand10	1a	2271.6174	377.13417	20
	1b	2544.4171	490.88049	18
	Total	2400.8383	450.33873	38
FarRand10	1a	2219.1489	585.86838	20
	1b	2035.5341	633.70014	18
	Total	2132.1735	607.78248	38

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Epoch	Sphericity Assumed	145198102.380	9	16133122.487	52.807	.000	.595
	Greenhouse-Geisser	145198102.380	4.981	29151977.603	52.807	.000	.595
	Huynh-Feldt	145198102.380	6.037	24050806.204	52.807	.000	.595
	Lower-bound	145198102.380	1.000	145198102.380	52.807	.000	.595
Epoch * Experiment	Sphericity Assumed	1216067.881	9	135118.653	.442	.911	.012
	Greenhouse-Geisser	1216067.881	4.981	244154.593	.442	.818	.012
	Huynh-Feldt	1216067.881	6.037	201431.096	.442	.851	.012
	Lower-bound	1216067.881	1.000	1216067.881	.442	.510	.012
Error(Epoch)	Sphericity Assumed	98985502.971	324	305510.812			
	Greenhouse-Geisser	98985502.971	179.306	552047.153			
	Huynh-Feldt	98985502.971	217.337	455446.943			
	Lower-bound	98985502.971	36.000	2749597.305			
Config	Sphericity Assumed	11759471.064	1	11759471.064	26.936	.000	.428
	Greenhouse-Geisser	11759471.064	1.000	11759471.064	26.936	.000	.428
	Huynh-Feldt	11759471.064	1.000	11759471.064	26.936	.000	.428

	Lower-bound	11759471.064	1.000	11759471.064	26.936	.000	.428
Config * Experiment	Sphericity Assumed	4617.304	1	4617.304	.011	.919	.000
	Greenhouse-Geisser	4617.304	1.000	4617.304	.011	.919	.000
	Huynh-Feldt	4617.304	1.000	4617.304	.011	.919	.000
	Lower-bound	4617.304	1.000	4617.304	.011	.919	.000
Error(Config)	Sphericity Assumed	15716707.548	36	436575.210			
	Greenhouse-Geisser	15716707.548	36.000	436575.210			
	Huynh-Feldt	15716707.548	36.000	436575.210			
	Lower-bound	15716707.548	36.000	436575.210			
Target	Sphericity Assumed	37873999.639	1	37873999.639	31.451	.000	.466
	Greenhouse-Geisser	37873999.639	1.000	37873999.639	31.451	.000	.466
	Huynh-Feldt	37873999.639	1.000	37873999.639	31.451	.000	.466
	Lower-bound	37873999.639	1.000	37873999.639	31.451	.000	.466
Target * Experiment	Sphericity Assumed	1948915.311	1	1948915.311	1.618	.211	.043
	Greenhouse-Geisser	1948915.311	1.000	1948915.311	1.618	.211	.043
	Huynh-Feldt	1948915.311	1.000	1948915.311	1.618	.211	.043
	Lower-bound	1948915.311	1.000	1948915.311	1.618	.211	.043
Error(Target)	Sphericity Assumed	43351491.852	36	1204208.107			
	Greenhouse-Geisser	43351491.852	36.000	1204208.107			
	Huynh-Feldt	43351491.852	36.000	1204208.107			
	Lower-bound	43351491.852	36.000	1204208.107			
Epoch * Config	Sphericity Assumed	1822187.406	9	202465.267	1.687	.091	.045
	Greenhouse-Geisser	1822187.406	6.665	273381.594	1.687	.117	.045
	Huynh-Feldt	1822187.406	8.566	212720.490	1.687	.095	.045
	Lower-bound	1822187.406	1.000	1822187.406	1.687	.202	.045
Epoch * Config * Experiment	Sphericity Assumed	660975.438	9	73441.715	.612	.787	.017
	Greenhouse-Geisser	660975.438	6.665	99165.716	.612	.738	.017
	Huynh-Feldt	660975.438	8.566	77161.668	.612	.779	.017
	Lower-bound	660975.438	1.000	660975.438	.612	.439	.017
Error(Epoch *Config)	Sphericity Assumed	38882373.603	324	120007.326			
	Greenhouse-Geisser	38882373.603	239.953	162041.591			
	Huynh-Feldt	38882373.603	308.380	126085.908			
	Lower-bound	38882373.603	36.000	1080065.933			
Epoch * Target	Sphericity Assumed	4026361.066	9	447373.452	2.844	.003	.073
	Greenhouse-Geisser	4026361.066	6.153	654347.071	2.844	.010	.073
	Huynh-Feldt	4026361.066	7.767	518384.866	2.844	.005	.073
	Lower-bound	4026361.066	1.000	4026361.066	2.844	.100	.073
Epoch * Target * Experiment	Sphericity Assumed	1300337.368	9	144481.930	.919	.509	.025
	Greenhouse-Geisser	1300337.368	6.153	211325.297	.919	.484	.025
	Huynh-Feldt	1300337.368	7.767	167415.490	.919	.499	.025
	Lower-bound	1300337.368	1.000	1300337.368	.919	.344	.025

Error(Epoch *Target)	Sphericity Assumed	50960682.981	324	157286.059			
	Greenhouse-Geisser	50960682.981	221.517	230053.150			
	Huynh-Feldt	50960682.981	279.617	182252.013			
	Lower-bound	50960682.981	36.000	1415574.527			
Config * Target	Sphericity Assumed	1038370.498	1	1038370.498	3.270	.079	.083
	Greenhouse-Geisser	1038370.498	1.000	1038370.498	3.270	.079	.083
	Huynh-Feldt	1038370.498	1.000	1038370.498	3.270	.079	.083
	Lower-bound	1038370.498	1.000	1038370.498	3.270	.079	.083
Config * Target * Experiment	Sphericity Assumed	159192.099	1	159192.099	.501	.483	.014
	Greenhouse-Geisser	159192.099	1.000	159192.099	.501	.483	.014
	Huynh-Feldt	159192.099	1.000	159192.099	.501	.483	.014
	Lower-bound	159192.099	1.000	159192.099	.501	.483	.014
Error(Config *Target)	Sphericity Assumed	11431400.388	36	317538.900			
	Greenhouse-Geisser	11431400.388	36.000	317538.900			
	Huynh-Feldt	11431400.388	36.000	317538.900			
	Lower-bound	11431400.388	36.000	317538.900			
Epoch * Config * Target	Sphericity Assumed	1335897.088	9	148433.010	1.150	.327	.031
	Greenhouse-Geisser	1335897.088	6.753	197814.893	1.150	.333	.031
	Huynh-Feldt	1335897.088	8.706	153444.264	1.150	.328	.031
	Lower-bound	1335897.088	1.000	1335897.088	1.150	.291	.031
Epoch * Config * Target * Experiment	Sphericity Assumed	604897.936	9	67210.882	.521	.860	.014
	Greenhouse-Geisser	604897.936	6.753	89571.137	.521	.813	.014
	Huynh-Feldt	604897.936	8.706	69479.992	.521	.854	.014
	Lower-bound	604897.936	1.000	604897.936	.521	.475	.014
Error(Epoch *Config*Target)	Sphericity Assumed	41833190.861	324	129114.787			
	Greenhouse-Geisser	41833190.861	243.118	172069.729			
	Huynh-Feldt	41833190.861	313.419	133473.837			
	Lower-bound	41833190.861	36.000	1162033.079			

Tests of Within-Subjects Contrasts

Source	Block	Config	Target	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Block	Linear			132222847.711	1	132222847.711	159.074	.000	.815
	Quadratic			9316115.562	1	9316115.562	21.296	.000	.372
	Cubic			1933755.709	1	1933755.709	5.169	.029	.126
	Order 4			33233.676	1	33233.676	.174	.679	.005

	Order 5			105373.959	1	105373.959	.448	.507	.012
	Order 6			22709.071	1	22709.071	.143	.707	.004
	Order 7			154706.173	1	154706.173	.864	.359	.023
	Order 8			123041.196	1	123041.196	.853	.362	.023
	Order 9			1286319.323	1	1286319.323	6.451	.016	.152
Block * Experiment	Linear			57016.308	1	57016.308	.069	.795	.002
	Quadratic			73070.188	1	73070.188	.167	.685	.005
	Cubic			13693.307	1	13693.307	.037	.849	.001
	Order 4			65069.041	1	65069.041	.342	.563	.009
	Order 5			337726.689	1	337726.689	1.437	.238	.038
	Order 6			319856.925	1	319856.925	2.015	.164	.053
	Order 7			86923.734	1	86923.734	.486	.490	.013
	Order 8			4785.208	1	4785.208	.033	.856	.001
	Order 9			257926.481	1	257926.481	1.293	.263	.035
Error(Block)	Linear			29923314.290	36	831203.175			
	Quadratic			15748557.202	36	437459.922			
	Cubic			13468615.661	36	374128.213			
	Order 4			6856605.558	36	190461.266			
	Order 5			8459418.990	36	234983.861			
	Order 6			5715076.261	36	158752.118			
	Order 7			6443435.382	36	178984.316			
	Order 8			5191627.063	36	144211.863			
	Order 9			7178852.564	36	199412.571			
Config		Linear		11759471.064	1	11759471.064	26.936	.000	.428
Config * Experiment		Linear		4617.304	1	4617.304	.011	.919	.000
Error(Config)		Linear		15716707.548	36	436575.210			
Target			Linear	37873999.639	1	37873999.639	31.451	.000	.466
Target * Experiment			Linear	1948915.311	1	1948915.311	1.618	.211	.043
Error(Target)			Linear	43351491.852	36	1204208.107			
Block * Config	Linear	Linear		1117495.761	1	1117495.761	7.730	.009	.177
	Quadratic	Linear		276494.262	1	276494.262	3.146	.085	.080
	Cubic	Linear		139798.287	1	139798.287	.984	.328	.027

	Order 4	Linear	39.843	1	39.843	.000	.987	.000
	Order 5	Linear	16420.860	1	16420.860	.169	.683	.005
	Order 6	Linear	110028.174	1	110028.174	1.094	.303	.029
	Order 7	Linear	55077.586	1	55077.586	.470	.497	.013
	Order 8	Linear	12424.812	1	12424.812	.077	.783	.002
	Order 9	Linear	94407.822	1	94407.822	1.130	.295	.030
Block * Config * Experiment	Linear	Linear	75397.452	1	75397.452	.522	.475	.014
	Quadratic	Linear	177574.621	1	177574.621	2.021	.164	.053
	Cubic	Linear	10252.347	1	10252.347	.072	.790	.002
	Order 4	Linear	105847.420	1	105847.420	.725	.400	.020
	Order 5	Linear	38636.448	1	38636.448	.398	.532	.011
	Order 6	Linear	73184.606	1	73184.606	.728	.399	.020
	Order 7	Linear	142564.418	1	142564.418	1.218	.277	.033
	Order 8	Linear	10710.874	1	10710.874	.066	.798	.002
	Order 9	Linear	26807.252	1	26807.252	.321	.575	.009
Error(Block*Config)	Linear	Linear	5204683.688	36	144574.547			
	Quadratic	Linear	3163799.035	36	87883.307			
	Cubic	Linear	5116816.966	36	142133.805			
	Order 4	Linear	5258193.385	36	146060.927			
	Order 5	Linear	3497076.819	36	97141.023			
	Order 6	Linear	3620896.508	36	100580.459			
	Order 7	Linear	4214281.110	36	117063.364			
	Order 8	Linear	5799071.536	36	161085.320			
	Order 9	Linear	3007554.556	36	83543.182			
Block * Target	Linear	Linear	1664505.731	1	1664505.731	5.842	.021	.140
	Quadratic	Linear	1673410.963	1	1673410.963	12.115	.001	.252
	Cubic	Linear	11011.981	1	11011.981	.105	.748	.003
	Order 4	Linear	159938.219	1	159938.219	1.238	.273	.033
	Order 5	Linear	121710.424	1	121710.424	.687	.413	.019
	Order 6	Linear	162420.664	1	162420.664	.910	.347	.025
	Order 7	Linear	199442.482	1	199442.482	1.247	.272	.033
	Order 8	Linear	19077.691	1	19077.691	.145	.705	.004
	Order 9	Linear	14842.910	1	14842.910	.134	.717	.004
Block * Target * Experiment	Linear	Linear	40078.736	1	40078.736	.141	.710	.004
	Quadratic	Linear	70404.647	1	70404.647	.510	.480	.014
	Cubic	Linear	467399.106	1	467399.106	4.440	.042	.110
	Order 4	Linear	285414.381	1	285414.381	2.209	.146	.058
	Order 5	Linear	93417.819	1	93417.819	.527	.472	.014
	Order 6	Linear	322.555	1	322.555	.002	.966	.000
	Order 7	Linear	59213.607	1	59213.607	.370	.547	.010
	Order 8	Linear	284064.541	1	284064.541	2.163	.150	.057

	Order 9		Linear	21.977	1	21.977	.000	.989	.000
Error(Block*Target)	Linear		Linear	10257913.959	36	284942.054			
	Quadratic		Linear	4972762.303	36	138132.286			
	Cubic		Linear	3789553.415	36	105265.373			
	Order 4		Linear	4651858.360	36	129218.288			
	Order 5		Linear	6376825.792	36	177134.050			
	Order 6		Linear	6428818.639	36	178578.296			
	Order 7		Linear	5758984.586	36	159971.794			
	Order 8		Linear	4727514.420	36	131319.845			
	Order 9		Linear	3996451.507	36	111012.542			
Config * Target		Linear	Linear	1038370.498	1	1038370.498	3.270	.079	.083
Config * Target * Experiment		Linear	Linear	159192.099	1	159192.099	.501	.483	.014
Error(Config*Target)		Linear	Linear	11431400.388	36	317538.900			
Block * Config * Target	Linear	Linear	Linear	229415.166	1	229415.166	1.238	.273	.033
	Quadratic	Linear	Linear	27212.957	1	27212.957	.175	.678	.005
	Cubic	Linear	Linear	2119.906	1	2119.906	.024	.879	.001
	Order 4	Linear	Linear	325273.298	1	325273.298	2.130	.153	.056
	Order 5	Linear	Linear	32738.310	1	32738.310	.302	.586	.008
	Order 6	Linear	Linear	11171.216	1	11171.216	.081	.778	.002
	Order 7	Linear	Linear	274311.643	1	274311.643	1.846	.183	.049
	Order 8	Linear	Linear	31736.478	1	31736.478	.306	.583	.008
	Order 9	Linear	Linear	401918.113	1	401918.113	5.070	.031	.123
Block * Config * Target * Experiment	Linear	Linear	Linear	1260.345	1	1260.345	.007	.935	.000
	Quadratic	Linear	Linear	36158.963	1	36158.963	.233	.632	.006
	Cubic	Linear	Linear	155145.882	1	155145.882	1.722	.198	.046
	Order 4	Linear	Linear	74353.888	1	74353.888	.487	.490	.013
	Order 5	Linear	Linear	95.051	1	95.051	.001	.977	.000
	Order 6	Linear	Linear	96881.217	1	96881.217	.699	.409	.019
	Order 7	Linear	Linear	215977.168	1	215977.168	1.453	.236	.039
	Order 8	Linear	Linear	19922.871	1	19922.871	.192	.664	.005
	Order 9	Linear	Linear	5102.551	1	5102.551	.064	.801	.002
Error(Block*Config*Target)	Linear	Linear	Linear	6673728.100	36	185381.336			
	Quadratic	Linear	Linear	5593055.641	36	155362.657			
	Cubic	Linear	Linear	3244309.924	36	90119.720			
	Order 4	Linear	Linear	5497766.894	36	152715.747			

	Order 5	Linear	Linear	3901309.590	36	108369.711			
	Order 6	Linear	Linear	4990155.304	36	138615.425			
	Order 7	Linear	Linear	5350740.756	36	148631.688			
	Order 8	Linear	Linear	3728468.377	36	103568.566			
	Order 9	Linear	Linear	2853656.275	36	79268.230			

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	9678726584.587	1	9678726584.587	1308.026	.000	.973
Experiment	25426.637	1	25426.637	.003	.954	.000
Error	266381582.009	36	7399488.389			

Estimated Marginal Means:

1. Experiment

Estimates

Experiment	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1a	2522.814	96.174	2327.765	2717.863
1b	2531.005	101.376	2325.405	2736.605

Pairwise Comparisons

(I) Experiment	(J) Experiment	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1a	1b	-8.191	139.737	.954	-291.591	275.208
1b	1a	8.191	139.737	.954	-275.208	291.591

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

2. Epoch

Estimates

Epoch	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3168.935	91.929	2982.495	3355.375
2	2923.953	87.267	2746.966	3100.939
3	2699.696	85.437	2526.422	2872.970
4	2608.357	92.257	2421.252	2795.462
5	2409.936	82.170	2243.288	2576.584
6	2473.933	94.338	2282.607	2665.258
7	2341.772	76.394	2186.838	2496.706
8	2270.714	76.408	2115.752	2425.676
9	2221.936	62.369	2095.445	2348.426
10	2149.863	62.153	2023.810	2275.916

Pairwise Comparisons

(I) Epoch	(J) Epoch	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	244.983*	60.964	.000	121.342	368.623
	3	469.239*	69.349	.000	328.594	609.885
	4	560.578*	78.341	.000	401.694	719.462
	5	758.999*	76.256	.000	604.345	913.654
	6	695.003*	75.951	.000	540.966	849.039
	7	827.163*	78.176	.000	668.615	985.712
	8	898.221*	81.199	.000	733.542	1062.900
	9	947.000*	73.920	.000	797.084	1096.916
	10	1019.072*	75.197	.000	866.567	1171.578
2	1	-244.983*	60.964	.000	-368.623	-121.342
	3	224.257*	63.823	.001	94.817	353.696
	4	315.596*	69.748	.000	174.140	457.051
	5	514.017*	65.599	.000	380.976	647.057
	6	450.020*	68.211	.000	311.683	588.358
	7	582.181*	70.992	.000	438.202	726.160
	8	653.239*	68.685	.000	513.939	792.539
	9	702.017*	72.116	.000	555.759	848.276
	10	774.090*	70.079	.000	631.963	916.217
3	1	-469.239*	69.349	.000	-609.885	-328.594
	2	-224.257*	63.823	.001	-353.696	-94.817

	4	91.339	55.266	.107	-20.745	203.423
	5	289.760*	47.837	.000	192.742	386.778
	6	225.764*	56.658	.000	110.856	340.671
	7	357.924*	64.507	.000	227.097	488.752
	8	428.982*	66.569	.000	293.974	563.991
	9	477.761*	65.388	.000	345.148	610.373
	10	549.833*	63.797	.000	420.447	679.220
4	1	-560.578*	78.341	.000	-719.462	-401.694
	2	-315.596*	69.748	.000	-457.051	-174.140
	3	-91.339	55.266	.107	-203.423	20.745
	5	198.421*	51.916	.001	93.131	303.711
	6	134.424*	64.568	.045	3.474	265.375
	7	266.585*	76.041	.001	112.367	420.803
	8	337.643*	78.242	.000	178.961	496.325
	9	386.421*	78.725	.000	226.760	546.083
	10	458.494*	68.694	.000	319.176	597.813
5	1	-758.999*	76.256	.000	-913.654	-604.345
	2	-514.017*	65.599	.000	-647.057	-380.976
	3	-289.760*	47.837	.000	-386.778	-192.742
	4	-198.421*	51.916	.001	-303.711	-93.131
	6	-63.997	54.111	.245	-173.738	45.745
	7	68.164	57.224	.241	-47.892	184.220
	8	139.222*	62.156	.031	13.163	265.281
	9	188.000*	62.060	.005	62.137	313.864
	10	260.073*	56.048	.000	146.403	373.743
6	1	-695.003*	75.951	.000	-849.039	-540.966
	2	-450.020*	68.211	.000	-588.358	-311.683
	3	-225.764*	56.658	.000	-340.671	-110.856
	4	-134.424*	64.568	.045	-265.375	-3.474
	5	63.997	54.111	.245	-45.745	173.738
	7	132.161*	52.247	.016	26.199	238.123
	8	203.219*	51.888	.000	97.985	308.452
	9	251.997*	59.552	.000	131.220	372.774
	10	324.070*	59.078	.000	204.253	443.886
7	1	-827.163*	78.176	.000	-985.712	-668.615
	2	-582.181*	70.992	.000	-726.160	-438.202
	3	-357.924*	64.507	.000	-488.752	-227.097
	4	-266.585*	76.041	.001	-420.803	-112.367
	5	-68.164	57.224	.241	-184.220	47.892
	6	-132.161*	52.247	.016	-238.123	-26.199
	8	71.058*	29.677	.022	10.869	131.246

	9	119.836*	41.349	.006	35.977	203.696
	10	191.909*	40.975	.000	108.808	275.010
8	1	-898.221*	81.199	.000	-1062.900	-733.542
	2	-653.239*	68.685	.000	-792.539	-513.939
	3	-428.982*	66.569	.000	-563.991	-293.974
	4	-337.643*	78.242	.000	-496.325	-178.961
	5	-139.222*	62.156	.031	-265.281	-13.163
	6	-203.219*	51.888	.000	-308.452	-97.985
	7	-71.058*	29.677	.022	-131.246	-10.869
	9	48.778	42.149	.255	-36.704	134.261
	10	120.851*	36.431	.002	46.966	194.737
9	1	-947.000*	73.920	.000	-1096.916	-797.084
	2	-702.017*	72.116	.000	-848.276	-555.759
	3	-477.761*	65.388	.000	-610.373	-345.148
	4	-386.421*	78.725	.000	-546.083	-226.760
	5	-188.000*	62.060	.005	-313.864	-62.137
	6	-251.997*	59.552	.000	-372.774	-131.220
	7	-119.836*	41.349	.006	-203.696	-35.977
	8	-48.778	42.149	.255	-134.261	36.704
	10	72.073	38.686	.071	-6.387	150.532
10	1	-1019.072*	75.197	.000	-1171.578	-866.567
	2	-774.090*	70.079	.000	-916.217	-631.963
	3	-549.833*	63.797	.000	-679.220	-420.447
	4	-458.494*	68.694	.000	-597.813	-319.176
	5	-260.073*	56.048	.000	-373.743	-146.403
	6	-324.070*	59.078	.000	-443.886	-204.253
	7	-191.909*	40.975	.000	-275.010	-108.808
	8	-120.851*	36.431	.002	-194.737	-46.966
	9	-72.073	38.686	.071	-150.532	6.387

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

3. Config

Estimates

Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Repeated	2438.830	71.608	2293.602	2584.058
Random	2614.989	72.191	2468.579	2761.398

Pairwise Comparisons

(I) Config	(J) Config	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Repeated	Random	-176.159*	33.942	.000	-244.997	-107.321
Random	Repeated	176.159*	33.942	.000	107.321	244.997

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

4. Target

Estimates

Target	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Near	2684.980	76.223	2530.393	2839.567
Far	2368.839	74.446	2217.856	2519.822

Pairwise Comparisons

(I) Target	(J) Target	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Near	Far	316.141*	56.372	.000	201.814	430.468
Far	Near	-316.141*	56.372	.000	-430.468	-201.814

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

5. Experiment * Epoch

Experiment	Epoch	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1a	1	3158.270	126.539	2901.637	3414.904
	2	2903.618	120.123	2659.997	3147.239
	3	2644.911	117.603	2406.401	2883.422
	4	2637.180	126.991	2379.631	2894.730
	5	2425.413	113.106	2196.023	2654.803
	6	2505.167	129.855	2241.808	2768.526
	7	2302.974	105.156	2089.708	2516.240
	8	2267.993	105.175	2054.689	2481.297
	9	2250.197	85.851	2076.084	2424.310
	10	2132.413	85.554	1958.902	2305.924
1b	1	3179.600	133.384	2909.084	3450.116
	2	2944.288	126.621	2687.489	3201.086
	3	2754.481	123.965	2503.069	3005.893
	4	2579.533	133.860	2308.053	2851.014
	5	2394.459	119.224	2152.660	2636.257
	6	2442.698	136.880	2165.094	2720.303
	7	2380.569	110.844	2155.767	2605.372
	8	2273.435	110.864	2048.593	2498.277
	9	2193.674	90.494	2010.143	2377.205
	10	2167.313	90.182	1984.416	2350.210

6. Experiment * Config

Experiment	Config	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1a	Repeated	2436.480	98.568	2236.574	2636.386
	Random	2609.148	99.370	2407.616	2810.680
1b	Repeated	2441.180	103.900	2230.461	2651.900
	Random	2620.830	104.745	2408.396	2833.263

7. Experiment * Target

Experiment	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1a	Near	2645.027	104.920	2432.239	2857.815
	Far	2400.600	102.474	2192.773	2608.428
1b	Near	2724.933	110.596	2500.634	2949.231
	Far	2337.077	108.017	2118.008	2556.147

8. Epoch * Config

Epoch	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	Repeated	3161.500	96.185	2966.428	3356.573
	Random	3176.370	103.589	2966.282	3386.459
2	Repeated	2860.196	98.361	2660.711	3059.681
	Random	2987.710	88.863	2807.488	3167.932
3	Repeated	2640.295	90.712	2456.322	2824.269
	Random	2759.097	88.119	2580.384	2937.810
4	Repeated	2505.909	100.227	2302.639	2709.178
	Random	2710.805	95.504	2517.113	2904.497
5	Repeated	2302.967	91.773	2116.843	2489.091
	Random	2516.905	87.910	2338.614	2695.196
6	Repeated	2353.829	92.544	2166.142	2541.516
	Random	2594.036	107.686	2375.639	2812.433
7	Repeated	2267.880	79.579	2106.485	2429.274
	Random	2415.664	85.289	2242.690	2588.638
8	Repeated	2160.398	81.730	1994.641	2326.155
	Random	2381.030	77.786	2223.273	2538.788
9	Repeated	2103.280	62.896	1975.721	2230.839
	Random	2340.591	71.077	2196.440	2484.743
10	Repeated	2032.046	65.556	1899.092	2165.001
	Random	2267.679	72.489	2120.664	2414.694

9. Epoch * Target

Epoch	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	Near	3238.943	107.321	3021.286	3456.600
	Far	3098.928	107.770	2880.360	3317.496
2	Near	2974.141	92.125	2787.303	3160.979
	Far	2873.765	112.627	2645.346	3102.183
3	Near	2860.405	89.288	2679.321	3041.488
	Far	2538.987	103.726	2328.621	2749.354
4	Near	2793.222	108.553	2573.067	3013.377
	Far	2423.492	89.292	2242.399	2604.585
5	Near	2597.575	94.798	2405.316	2789.834
	Far	2222.297	88.905	2041.988	2402.605
6	Near	2671.202	102.660	2462.998	2879.406
	Far	2276.663	100.318	2073.209	2480.117
7	Near	2558.601	93.614	2368.743	2748.460
	Far	2124.942	78.081	1966.587	2283.298
8	Near	2440.878	81.865	2274.848	2606.908
	Far	2100.550	79.627	1939.060	2262.041
9	Near	2399.487	66.515	2264.588	2534.386
	Far	2044.384	76.918	1888.386	2200.382
10	Near	2315.346	63.380	2186.805	2443.886
	Far	1984.380	77.020	1828.177	2140.583

10. Config * Target

Config	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Repeated	Near	2623.074	83.739	2453.243	2792.905
	Far	2254.586	73.375	2105.774	2403.398
Random	Near	2746.886	73.031	2598.772	2895.001
	Far	2483.091	83.453	2313.840	2652.342

11. Experiment * Epoch * Config

Experiment	Epoch	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1a	1	Repeated	3136.337	132.398	2867.821	3404.853
		Random	3180.204	142.590	2891.018	3469.389
	2	Repeated	2792.133	135.393	2517.543	3066.723
		Random	3015.103	122.319	2767.028	3263.177
	3	Repeated	2602.398	124.865	2349.160	2855.636
		Random	2687.425	121.295	2441.427	2933.422
	4	Repeated	2549.180	137.962	2269.381	2828.979
		Random	2725.181	131.461	2458.565	2991.797
	5	Repeated	2332.769	126.325	2076.570	2588.967
		Random	2518.058	121.008	2272.642	2763.474
	6	Repeated	2397.765	127.386	2139.414	2656.115
		Random	2612.569	148.229	2311.946	2913.192
	7	Repeated	2258.030	109.541	2035.872	2480.189
		Random	2347.918	117.400	2109.820	2586.016
	8	Repeated	2144.257	112.502	1916.093	2372.421
		Random	2391.729	107.072	2174.577	2608.882
	9	Repeated	2132.486	86.576	1956.902	2308.070
		Random	2367.908	97.837	2169.485	2566.332
	10	Repeated	2019.442	90.238	1836.431	2202.453
		Random	2245.383	99.781	2043.018	2447.749
1b	1	Repeated	3186.664	139.560	2903.623	3469.704
		Random	3172.536	150.303	2867.708	3477.365
	2	Repeated	2928.258	142.717	2638.815	3217.702
		Random	2960.317	128.936	2698.823	3221.810
	3	Repeated	2678.193	131.619	2411.257	2945.129
		Random	2830.769	127.856	2571.465	3090.073
	4	Repeated	2462.637	145.424	2167.703	2757.572
		Random	2696.430	138.572	2415.392	2977.467
	5	Repeated	2273.165	133.158	2003.108	2543.222
		Random	2515.752	127.554	2257.061	2774.444
	6	Repeated	2309.894	134.277	2037.568	2582.219
		Random	2575.503	156.247	2258.619	2892.387
	7	Repeated	2277.729	115.466	2043.554	2511.905
		Random	2483.410	123.750	2232.433	2734.387

	8	Repeated	2176.539	118.587	1936.033	2417.045
		Random	2370.331	112.864	2141.432	2599.230
	9	Repeated	2074.074	91.259	1888.992	2259.156
		Random	2313.274	103.130	2104.118	2522.431
	10	Repeated	2044.650	95.119	1851.740	2237.561
		Random	2289.976	105.179	2076.664	2503.288

12. Experiment * Epoch * Target

					95% Confidence Interval	
Experiment	Epoch	Target	Mean	Std. Error	Lower Bound	Upper Bound
1a	1	Near	3232.660	147.727	2933.056	3532.263
		Far	3083.881	148.345	2783.023	3384.739
	2	Near	2892.240	126.809	2635.058	3149.421
		Far	2914.996	155.031	2600.579	3229.412
	3	Near	2716.716	122.904	2467.455	2965.976
		Far	2573.107	142.779	2283.539	2862.675
	4	Near	2815.851	149.422	2512.809	3118.893
		Far	2458.510	122.910	2209.237	2707.784
	5	Near	2593.249	130.489	2328.606	2857.893
		Far	2257.577	122.378	2009.384	2505.771
	6	Near	2671.168	141.311	2384.576	2957.760
		Far	2339.165	138.087	2059.112	2619.218
	7	Near	2516.420	128.859	2255.081	2777.759
		Far	2089.528	107.478	1871.553	2307.504
	8	Near	2400.267	112.687	2171.728	2628.806
		Far	2135.719	109.606	1913.428	2358.010
	9	Near	2384.479	91.558	2198.791	2570.167
		Far	2115.915	105.878	1901.185	2330.646
	10	Near	2227.221	87.242	2050.286	2404.157
		Far	2037.604	106.017	1822.591	2252.617
1b	1	Near	3245.225	155.718	2929.416	3561.035
		Far	3113.975	156.369	2796.843	3431.107
	2	Near	3056.042	133.669	2784.949	3327.135
		Far	2832.533	163.417	2501.109	3163.957
	3	Near	3004.094	129.552	2741.350	3266.838
		Far	2504.868	150.502	2199.636	2810.100
	4	Near	2770.594	157.505	2451.160	3090.028
		Far	2388.473	129.559	2125.715	2651.230

	5	Near	2601.901	137.547	2322.942	2880.860
		Far	2187.016	128.997	1925.397	2448.635
	6	Near	2671.236	148.955	2369.142	2973.330
		Far	2214.161	145.556	1918.959	2509.362
	7	Near	2600.782	135.830	2325.307	2876.258
		Far	2160.356	113.292	1930.590	2390.123
	8	Near	2481.488	118.782	2240.587	2722.390
		Far	2065.382	115.535	1831.066	2299.697
	9	Near	2414.495	96.510	2218.763	2610.227
		Far	1972.853	111.605	1746.507	2199.198
	10	Near	2403.470	91.961	2216.964	2589.977
		Far	1931.156	111.752	1704.512	2157.799

13. Experiment * Config * Target

					95% Confidence Interval	
Experiment	Config	Target	Mean	Std. Error	Lower Bound	Upper Bound
1a	Repeated	Near	2595.114	115.267	2361.343	2828.886
		Far	2277.845	101.001	2073.006	2482.684
	Random	Near	2694.940	100.527	2491.061	2898.819
		Far	2523.356	114.873	2290.383	2756.329
1b	Repeated	Near	2651.033	121.502	2404.617	2897.450
		Far	2231.327	106.464	2015.408	2447.247
	Random	Near	2798.833	105.965	2583.926	3013.739
		Far	2442.827	121.087	2197.252	2688.402

14. Epoch * Config * Target

Epoch	Config	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	Repeated	Near	3216.077	112.410	2988.099	3444.056
		Far	3106.924	125.762	2851.866	3361.981
	Random	Near	3261.808	118.398	3021.685	3501.931
		Far	3090.932	119.292	2848.996	3332.868
2	Repeated	Near	2939.727	108.433	2719.814	3159.639
		Far	2780.665	135.666	2505.522	3055.807
	Random	Near	3008.555	98.632	2808.520	3208.591
		Far	2966.864	117.717	2728.122	3205.606
3	Repeated	Near	2813.226	98.382	2613.698	3012.754
		Far	2467.364	108.623	2247.066	2687.663
	Random	Near	2907.583	99.553	2705.681	3109.485
		Far	2610.610	115.007	2377.365	2843.856
4	Repeated	Near	2742.969	126.259	2486.904	2999.034
		Far	2268.848	91.095	2084.098	2453.599
	Random	Near	2843.476	102.915	2634.754	3052.197
		Far	2578.135	109.113	2356.843	2799.427
5	Repeated	Near	2492.990	113.928	2261.933	2724.048
		Far	2112.943	93.402	1923.515	2302.372
	Random	Near	2702.160	99.395	2500.578	2903.741
		Far	2331.650	109.662	2109.246	2554.054
6	Repeated	Near	2581.436	110.035	2358.275	2804.598
		Far	2126.222	92.670	1938.277	2314.166
	Random	Near	2760.968	113.269	2531.247	2990.689
		Far	2427.104	129.144	2165.188	2689.020
7	Repeated	Near	2475.519	98.931	2274.877	2676.161
		Far	2060.241	82.609	1892.702	2227.779
	Random	Near	2641.684	103.596	2431.582	2851.785
		Far	2189.644	94.252	1998.492	2380.797
8	Repeated	Near	2419.975	96.812	2223.631	2616.319
		Far	1900.821	85.015	1728.403	2073.238
	Random	Near	2461.780	75.395	2308.872	2614.689
		Far	2300.280	97.925	2101.678	2498.882
9	Repeated	Near	2326.144	78.693	2166.546	2485.741
		Far	1880.416	74.535	1729.252	2031.580
	Random	Near	2472.831	68.348	2334.215	2611.446
		Far	2208.352	98.812	2007.952	2408.753

10	Repeated	Near	2222.674	75.599	2069.353	2375.995
		Far	1841.418	75.107	1689.094	1993.743
	Random	Near	2408.017	70.595	2264.844	2551.191
		Far	2127.342	98.918	1926.727	2327.956

15. Experiment * Epoch * Config * Target

						95% Confidence Interval	
Experiment	Epoch	Config	Target	Mean	Std. Error	Lower Bound	Upper Bound
1a	1	Repeated	Near	3208.879	154.732	2895.068	3522.690
			Far	3063.795	173.111	2712.709	3414.880
		Random	Near	3256.441	162.975	2925.913	3586.968
			Far	3103.967	164.205	2770.944	3436.991
	2	Repeated	Near	2820.773	149.257	2518.065	3123.481
			Far	2763.493	186.743	2384.761	3142.225
		Random	Near	2963.707	135.767	2688.360	3239.055
			Far	3066.498	162.037	2737.871	3395.126
	3	Repeated	Near	2686.798	135.422	2412.149	2961.447
			Far	2517.998	149.519	2214.758	2821.237
		Random	Near	2746.633	137.033	2468.717	3024.550
			Far	2628.216	158.307	2307.155	2949.277
	4	Repeated	Near	2822.397	173.795	2469.925	3174.869
			Far	2275.963	125.392	2021.655	2530.270
		Random	Near	2809.304	141.662	2522.000	3096.608
			Far	2641.058	150.194	2336.451	2945.665
	5	Repeated	Near	2517.975	156.822	2199.926	2836.024
			Far	2147.562	128.568	1886.815	2408.310
		Random	Near	2668.523	136.816	2391.048	2945.999
			Far	2367.592	150.948	2061.454	2673.729
	6	Repeated	Near	2582.021	151.463	2274.841	2889.201
			Far	2213.508	127.560	1954.804	2472.213
		Random	Near	2760.316	155.915	2444.106	3076.525
			Far	2464.822	177.766	2104.296	2825.348
	7	Repeated	Near	2458.662	136.178	2182.480	2734.845
			Far	2057.398	113.710	1826.782	2288.013
		Random	Near	2574.177	142.599	2284.974	2863.381
			Far	2121.659	129.738	1858.539	2384.779
	8	Repeated	Near	2380.404	133.261	2110.138	2650.670
			Far	1908.109	117.022	1670.777	2145.442

		Random	Near	2420.130	103.781	2209.653	2630.608
			Far	2363.328	134.794	2089.954	2636.703
	9	Repeated	Near	2290.408	108.321	2070.723	2510.093
			Far	1974.564	102.597	1766.488	2182.640
		Random	Near	2478.550	94.080	2287.747	2669.353
			Far	2257.267	136.014	1981.417	2533.117
	10	Repeated	Near	2182.825	104.061	1971.779	2393.871
			Far	1856.059	103.385	1646.386	2065.733
		Random	Near	2271.617	97.174	2074.540	2468.695
			Far	2219.149	136.160	1943.005	2495.293
1b	1	Repeated	Near	3223.275	163.102	2892.489	3554.061
			Far	3150.052	182.475	2779.976	3520.129
		Random	Near	3267.176	171.790	2918.769	3615.583
			Far	3077.897	173.087	2726.860	3428.934
	2	Repeated	Near	3058.681	157.331	2739.598	3377.763
			Far	2797.836	196.844	2398.617	3197.055
		Random	Near	3053.404	143.111	2763.162	3343.645
			Far	2867.230	170.802	2520.827	3213.634
	3	Repeated	Near	2939.655	142.748	2650.149	3229.161
			Far	2416.731	157.607	2097.089	2736.374
		Random	Near	3068.533	144.446	2775.583	3361.483
			Far	2593.005	166.870	2254.577	2931.432
	4	Repeated	Near	2663.541	183.196	2292.003	3035.079
			Far	2261.734	132.175	1993.670	2529.798
		Random	Near	2877.647	149.325	2574.802	3180.492
			Far	2515.212	158.318	2194.128	2836.296
	5	Repeated	Near	2468.006	165.305	2132.753	2803.259
			Far	2078.324	135.522	1803.472	2353.176
		Random	Near	2735.796	144.217	2443.311	3028.281
			Far	2295.708	159.114	1973.011	2618.406
	6	Repeated	Near	2580.852	159.656	2257.055	2904.648
			Far	2038.935	134.460	1766.237	2311.634
		Random	Near	2761.620	164.349	2428.306	3094.935
			Far	2389.386	187.382	2009.358	2769.414
	7	Repeated	Near	2492.375	143.545	2201.253	2783.497
			Far	2063.083	119.861	1819.993	2306.173
		Random	Near	2709.190	150.312	2404.343	3014.037
			Far	2257.630	136.755	1980.277	2534.983

8	Repeated	Near	2459.546	140.470	2174.661	2744.432
		Far	1893.532	123.352	1643.362	2143.702
	Random	Near	2503.431	109.395	2281.568	2725.293
		Far	2237.231	142.085	1949.069	2525.394
9	Repeated	Near	2361.880	114.180	2130.311	2593.448
		Far	1786.268	108.147	1566.936	2005.599
	Random	Near	2467.111	99.169	2265.987	2668.236
		Far	2159.438	143.372	1868.666	2450.209
10	Repeated	Near	2262.523	109.690	2040.061	2484.985
		Far	1826.777	108.977	1605.762	2047.793
	Random	Near	2544.417	102.430	2336.679	2752.155
		Far	2035.534	143.525	1744.452	2326.616

T-Test on the Contextual Cueing Effect for near and far targets

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	NearRep	2618.4425	38	509.06934	82.58195
	NearRand	2742.0097	38	446.05176	72.35915
Pair 2	FarRep	2249.4236	38	444.18434	72.05622
	FarRand	2478.7763	38	508.95609	82.56358

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	NearRep - NearRand	-123.56726	232.03445	37.64096	-199.83509	-47.29944	-3.283	37	.002
Pair 2	FarRep - FarRand	-229.35262	304.45626	49.38933	-329.42490	-129.28034	-4.644	37	.000

Appendix E: SPSS Output for Experiment 2 Allocentric Data

Four-way mixed-model ANOVA

Within-subject Factors:

- Test Period: 1 vs. 2 vs. 3
- Config: Repeated vs. Random
- Target: Near vs. Far

Between-subject Factor:

- Condition: Proximal vs. Distal

Dependent Variable:

- Reaction Time

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
NearRep1	Proximal	2694.5118	462.48672	33
	Distal	2731.3841	432.15552	29
	Total	2711.7585	445.28178	62
FarRep1	Proximal	2225.8906	523.27511	33
	Distal	2299.5510	542.90931	29
	Total	2260.3447	529.44301	62
NearRand1	Proximal	2783.0839	541.64705	33
	Distal	2890.4007	511.76387	29
	Total	2833.2805	526.34279	62
FarRand1	Proximal	2326.4418	571.70557	33
	Distal	2355.9731	464.15082	29
	Total	2340.2548	520.16361	62
NearRep2	Proximal	2406.8285	407.39263	33
	Distal	2339.9834	374.68387	29
	Total	2375.5623	390.68737	62
FarRep2	Proximal	1991.0855	479.56185	33
	Distal	1988.9631	473.34355	29
	Total	1990.0927	472.74800	62
NearRand2	Proximal	2564.8182	535.60959	33
	Distal	2695.1103	614.89537	29
	Total	2625.7613	573.01067	62

FarRand2	Proximal	2092.9318	432.40614	33
	Distal	2239.1341	627.31465	29
	Total	2161.3168	533.03646	62
NearRep3	Proximal	2264.4082	423.17456	33
	Distal	2149.0655	346.20509	29
	Total	2210.4576	390.28847	62
FarRep3	Proximal	1770.3655	439.19269	33
	Distal	1783.6569	456.45196	29
	Total	1776.5824	443.69848	62
NearRand3	Proximal	2497.8897	467.67376	33
	Distal	2474.4669	443.72600	29
	Total	2486.9339	453.04915	62
FarRand3	Proximal	1883.1870	457.77668	33
	Distal	1985.4859	425.51892	29
	Total	1931.0365	442.37242	62

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Sphericity Assumed	23765168.426	2	11882584.213	61.479	.000	.506
	Greenhouse-Geisser	23765168.426	1.913	12422670.642	61.479	.000	.506
	Huynh-Feldt	23765168.426	2.000	11882584.213	61.479	.000	.506
	Lower-bound	23765168.426	1.000	23765168.426	61.479	.000	.506
TestPeriod * Condition	Sphericity Assumed	164661.029	2	82330.515	.426	.654	.007
	Greenhouse-Geisser	164661.029	1.913	86072.596	.426	.645	.007
	Huynh-Feldt	164661.029	2.000	82330.515	.426	.654	.007
	Lower-bound	164661.029	1.000	164661.029	.426	.516	.007
Error(TestPeriod)	Sphericity Assumed	23193352.546	120	193277.938			
	Greenhouse-Geisser	23193352.546	114.783	202062.794			
	Huynh-Feldt	23193352.546	120.000	193277.938			
	Lower-bound	23193352.546	60.000	386555.876			
Config	Sphericity Assumed	5908487.028	1	5908487.028	39.113	.000	.395
	Greenhouse-Geisser	5908487.028	1.000	5908487.028	39.113	.000	.395
	Huynh-Feldt	5908487.028	1.000	5908487.028	39.113	.000	.395
	Lower-bound	5908487.028	1.000	5908487.028	39.113	.000	.395
Config * Condition	Sphericity Assumed	392938.841	1	392938.841	2.601	.112	.042
	Greenhouse-Geisser	392938.841	1.000	392938.841	2.601	.112	.042
	Huynh-Feldt	392938.841	1.000	392938.841	2.601	.112	.042

	Lower-bound	392938.841	1.000	392938.841	2.601	.112	.042
Error(Config)	Sphericity Assumed	9063641.908	60	151060.698			
	Greenhouse-Geisser	9063641.908	60.000	151060.698			
	Huynh-Feldt	9063641.908	60.000	151060.698			
	Lower-bound	9063641.908	60.000	151060.698			
Target	Sphericity Assumed	39610750.795	1	39610750.795	115.888	.000	.659
	Greenhouse-Geisser	39610750.795	1.000	39610750.795	115.888	.000	.659
	Huynh-Feldt	39610750.795	1.000	39610750.795	115.888	.000	.659
	Lower-bound	39610750.795	1.000	39610750.795	115.888	.000	.659
Target * Condition	Sphericity Assumed	111175.199	1	111175.199	.325	.571	.005
	Greenhouse-Geisser	111175.199	1.000	111175.199	.325	.571	.005
	Huynh-Feldt	111175.199	1.000	111175.199	.325	.571	.005
	Lower-bound	111175.199	1.000	111175.199	.325	.571	.005
Error(Target)	Sphericity Assumed	20508143.063	60	341802.384			
	Greenhouse-Geisser	20508143.063	60.000	341802.384			
	Huynh-Feldt	20508143.063	60.000	341802.384			
	Lower-bound	20508143.063	60.000	341802.384			
TestPeriod * Config	Sphericity Assumed	555846.368	2	277923.184	2.510	.086	.040
	Greenhouse-Geisser	555846.368	1.760	315850.521	2.510	.093	.040
	Huynh-Feldt	555846.368	1.839	302236.561	2.510	.090	.040
	Lower-bound	555846.368	1.000	555846.368	2.510	.118	.040
TestPeriod * Config * Condition	Sphericity Assumed	196585.088	2	98292.544	.888	.414	.015
	Greenhouse-Geisser	196585.088	1.760	111706.231	.888	.403	.015
	Huynh-Feldt	196585.088	1.839	106891.408	.888	.407	.015
	Lower-bound	196585.088	1.000	196585.088	.888	.350	.015
Error(TestPeriod*Config)	Sphericity Assumed	13288795.967	120	110739.966			
	Greenhouse-Geisser	13288795.967	105.590	125852.315			
	Huynh-Feldt	13288795.967	110.347	120427.761			
	Lower-bound	13288795.967	60.000	221479.933			
TestPeriod * Target	Sphericity Assumed	149202.181	2	74601.090	.798	.452	.013
	Greenhouse-Geisser	149202.181	1.957	76237.738	.798	.450	.013
	Huynh-Feldt	149202.181	2.000	74601.090	.798	.452	.013
	Lower-bound	149202.181	1.000	149202.181	.798	.375	.013
TestPeriod * Target * Condition	Sphericity Assumed	170056.659	2	85028.329	.910	.405	.015
	Greenhouse-Geisser	170056.659	1.957	86893.737	.910	.404	.015
	Huynh-Feldt	170056.659	2.000	85028.329	.910	.405	.015
	Lower-bound	170056.659	1.000	170056.659	.910	.344	.015

Error(TestPeriod*Target)	Sphericity Assumed	11212896.449	120	93440.804			
	Greenhouse-Geisser	11212896.449	117.424	95490.770			
	Huynh-Feldt	11212896.449	120.000	93440.804			
	Lower-bound	11212896.449	60.000	186881.607			
Config * Target	Sphericity Assumed	316380.377	1	316380.377	2.264	.138	.036
	Greenhouse-Geisser	316380.377	1.000	316380.377	2.264	.138	.036
	Huynh-Feldt	316380.377	1.000	316380.377	2.264	.138	.036
	Lower-bound	316380.377	1.000	316380.377	2.264	.138	.036
Config * Target * Condition	Sphericity Assumed	35572.612	1	35572.612	.255	.616	.004
	Greenhouse-Geisser	35572.612	1.000	35572.612	.255	.616	.004
	Huynh-Feldt	35572.612	1.000	35572.612	.255	.616	.004
	Lower-bound	35572.612	1.000	35572.612	.255	.616	.004
Error(Config*Target)	Sphericity Assumed	8386295.322	60	139771.589			
	Greenhouse-Geisser	8386295.322	60.000	139771.589			
	Huynh-Feldt	8386295.322	60.000	139771.589			
	Lower-bound	8386295.322	60.000	139771.589			
TestPeriod * Config * Target	Sphericity Assumed	45634.092	2	22817.046	.247	.782	.004
	Greenhouse-Geisser	45634.092	1.873	24362.695	.247	.767	.004
	Huynh-Feldt	45634.092	1.964	23241.016	.247	.778	.004
	Lower-bound	45634.092	1.000	45634.092	.247	.621	.004
TestPeriod * Config * Target * Condition	Sphericity Assumed	24310.309	2	12155.154	.131	.877	.002
	Greenhouse-Geisser	24310.309	1.873	12978.556	.131	.864	.002
	Huynh-Feldt	24310.309	1.964	12381.013	.131	.873	.002
	Lower-bound	24310.309	1.000	24310.309	.131	.718	.002
Error(TestPeriod*Config*Target)	Sphericity Assumed	11095153.219	120	92459.610			
	Greenhouse-Geisser	11095153.219	112.387	98722.916			
	Huynh-Feldt	11095153.219	117.811	94177.630			
	Lower-bound	11095153.219	60.000	184919.220			

Tests of Within-Subjects Contrasts

Source	TestPeriod	Config	Target	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Linear			23618187.658	1	23618187.658	137.019	.000	.695
	Quadratic			146980.768	1	146980.768	.686	.411	.011
TestPeriod * Condition	Linear			141235.647	1	141235.647	.819	.369	.013
	Quadratic			23425.382	1	23425.382	.109	.742	.002
	Linear			10342276.668	60	172371.278			

Error(TestPeriod)	Quadratic			12851075.878	60	214184.598			
Config		Linear		5908487.028	1	5908487.028	39.113	.000	.395
Config * Condition		Linear		392938.841	1	392938.841	2.601	.112	.042
Error(Config)		Linear		9063641.908	60	151060.698			
Target			Linear	39610750.795	1	39610750.795	115.888	.000	.659
Target * Condition			Linear	111175.199	1	111175.199	.325	.571	.005
Error(Target)			Linear	20508143.063	60	341802.384			
TestPeriod * Config	Linear	Linear		424348.838	1	424348.838	4.884	.031	.075
	Quadratic	Linear		131497.530	1	131497.530	.977	.327	.016
TestPeriod * Config * Condition	Linear	Linear		46122.922	1	46122.922	.531	.469	.009
	Quadratic	Linear		150462.167	1	150462.167	1.118	.295	.018
Error(TestPeriod*Config)	Linear	Linear		5212891.496	60	86881.525			
	Quadratic	Linear		8075904.471	60	134598.408			
TestPeriod * Target	Linear		Linear	9894.430	1	9894.430	.093	.761	.002
	Quadratic		Linear	139307.750	1	139307.750	1.720	.195	.028
TestPeriod * Target * Condition	Linear		Linear	168311.384	1	168311.384	1.589	.212	.026
	Quadratic		Linear	1745.274	1	1745.274	.022	.884	.000
Error(TestPeriod*Target)	Linear		Linear	6353378.725	60	105889.645			
	Quadratic		Linear	4859517.725	60	80991.962			
Config * Target		Linear	Linear	316380.377	1	316380.377	2.264	.138	.036
Config * Target * Condition		Linear	Linear	35572.612	1	35572.612	.255	.616	.004
Error(Config*Target)		Linear	Linear	8386295.322	60	139771.589			
TestPeriod * Config * Target	Linear	Linear	Linear	45531.184	1	45531.184	.579	.450	.010
	Quadratic	Linear	Linear	102.908	1	102.908	.001	.975	.000
TestPeriod * Config * Target * Condition	Linear	Linear	Linear	24056.616	1	24056.616	.306	.582	.005
	Quadratic	Linear	Linear	253.693	1	253.693	.002	.961	.000

Error(TestPeriod*Config*Target)	Linear	Linear	Linear	4716513.539	60	78608.559			
	Quadratic	Linear	Linear	6378639.679	60	106310.661			

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	3952766081.290	1	3952766081.290	3360.369	.000	.982
Condition	239755.725	1	239755.725	.204	.653	.003
Error	70577358.745	60	1176289.312			

Estimated Marginal Means:

1. Condition

Estimates

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Proximal	2291.787	54.502	2182.767	2400.806
Distal	2327.765	58.139	2211.469	2444.060

Pairwise Comparisons

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Proximal	Distal	-35.978	79.690	.653	-195.382	123.427
Distal	Proximal	35.978	79.690	.653	-123.427	195.382

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

2. TestPeriod

Estimates

TestPeriod	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2538.405	48.799	2440.792	2636.018
2	2289.857	47.721	2194.402	2385.312
3	2101.066	40.860	2019.334	2182.798

Pairwise Comparisons

(I) TestPeriod	(J) TestPeriod	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	248.548*	43.576	.000	161.382	335.713
	3	437.339*	37.362	.000	362.604	512.074
2	1	-248.548*	43.576	.000	-335.713	-161.382
	3	188.791*	37.428	.000	113.925	263.658
3	1	-437.339*	37.362	.000	-512.074	-362.604
	2	-188.791*	37.428	.000	-263.658	-113.925

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

3. Config

Estimates

Config	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Repeated	2220.475	42.755	2134.951	2305.998
Random	2399.077	41.893	2315.278	2482.876

Pairwise Comparisons

(I) Config	(J) Config	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Repeated	Random	-178.602*	28.558	.000	-235.727	-121.478
Random	Repeated	178.602*	28.558	.000	121.478	235.727

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

4. Target

Estimates

Target	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Near	2540.996	44.820	2451.343	2630.649
Far	2078.556	45.707	1987.128	2169.983

Pairwise Comparisons

(I) Target	(J) Target	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Near	Far	462.440*	42.957	.000	376.513	548.368
Far	Near	-462.440*	42.957	.000	-548.368	-376.513

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

5. Condition * TestPeriod

Condition	TestPeriod	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Proximal	1	2507.482	66.749	2373.964	2641.000
	2	2263.916	65.274	2133.349	2394.483
	3	2103.963	55.889	1992.167	2215.758
Distal	1	2569.327	71.204	2426.898	2711.756
	2	2315.798	69.630	2176.517	2455.078
	3	2098.169	59.619	1978.912	2217.425

6. Condition * Config

Condition	Config	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Proximal	Repeated	2225.515	58.482	2108.533	2342.497
	Random	2358.059	57.303	2243.436	2472.681
Distal	Repeated	2215.434	62.385	2090.645	2340.223
	Random	2440.095	61.127	2317.823	2562.367

7. Condition * Target

Condition	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Proximal	Near	2535.257	61.306	2412.626	2657.887
	Far	2048.317	62.520	1923.259	2173.375
Distal	Near	2546.735	65.398	2415.921	2677.550
	Far	2108.794	66.692	1975.390	2242.198

8. TestPeriod * Config

TestPeriod	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	Repeated	2487.834	52.931	2381.956	2593.713
	Random	2588.975	55.562	2477.834	2700.115
2	Repeated	2181.715	48.112	2085.477	2277.953
	Random	2397.999	56.859	2284.264	2511.733
3	Repeated	1991.874	46.305	1899.250	2084.498
	Random	2210.257	45.744	2118.756	2301.758

9. TestPeriod * Target

TestPeriod	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	Near	2774.845	55.894	2663.040	2886.651
	Far	2301.964	58.406	2185.135	2418.793
2	Near	2501.685	53.508	2394.652	2608.718
	Far	2078.029	55.002	1968.009	2188.048
3	Near	2346.458	48.136	2250.170	2442.745
	Far	1855.674	46.870	1761.920	1949.428

10. Config * Target

Config	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Repeated	Near	2431.030	45.030	2340.957	2521.104
	Far	2009.919	51.508	1906.887	2112.950
Random	Near	2650.962	52.496	2545.953	2755.970
	Far	2147.192	48.264	2050.650	2243.734

11. Condition * TestPeriod * Config

Condition	TestPeriod	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Proximal	1	Repeated	2460.201	72.401	2315.377	2605.025
		Random	2554.763	76.000	2402.741	2706.785
	2	Repeated	2198.957	65.809	2067.320	2330.594
		Random	2328.875	77.773	2173.305	2484.445
	3	Repeated	2017.387	63.338	1890.692	2144.082
		Random	2190.538	62.570	2065.380	2315.697
Distal	1	Repeated	2515.468	77.233	2360.978	2669.957
		Random	2623.187	81.072	2461.020	2785.354
	2	Repeated	2164.473	70.201	2024.051	2304.896
		Random	2467.122	82.964	2301.170	2633.075
	3	Repeated	1966.361	67.565	1831.211	2101.511
		Random	2229.976	66.746	2096.465	2363.487

12. Condition * TestPeriod * Target

Condition	TestPeriod	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Proximal	1	Near	2738.798	76.454	2585.867	2891.729
		Far	2276.166	79.890	2116.363	2435.969
	2	Near	2485.823	73.191	2339.421	2632.226
		Far	2042.009	75.233	1891.520	2192.497
	3	Near	2381.149	65.843	2249.444	2512.854
		Far	1826.776	64.110	1698.537	1955.016
Distal	1	Near	2810.892	81.557	2647.755	2974.030
		Far	2327.762	85.221	2157.294	2498.230
	2	Near	2517.547	78.075	2361.373	2673.720
		Far	2114.049	80.254	1953.517	2274.581
	3	Near	2311.766	70.237	2171.272	2452.261
		Far	1884.571	68.389	1747.773	2021.369

13. Condition * Config * Target

Condition	Config	Target	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Proximal	Repeated	Near	2455.249	61.594	2332.044	2578.455
		Far	1995.781	70.455	1854.850	2136.711
	Random	Near	2615.264	71.806	2471.630	2758.898
		Far	2100.854	66.017	1968.800	2232.907
Distal	Repeated	Near	2406.811	65.704	2275.383	2538.239
		Far	2024.057	75.157	1873.722	2174.393
	Random	Near	2686.659	76.598	2533.440	2839.879
		Far	2193.531	70.423	2052.665	2334.397

14. TestPeriod * Config * Target

TestPeriod	Config	Target	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
1	Repeated	Near	2712.948	57.090	2598.752	2827.144
		Far	2262.721	67.772	2127.156	2398.286
	Random	Near	2836.742	67.185	2702.353	2971.132
		Far	2341.207	66.721	2207.746	2474.669
2	Repeated	Near	2373.406	49.948	2273.496	2473.316
		Far	1990.024	60.664	1868.679	2111.369
	Random	Near	2629.964	73.047	2483.849	2776.080
		Far	2166.033	67.746	2030.521	2301.545
3	Repeated	Near	2206.737	49.526	2107.670	2305.803
		Far	1777.011	56.930	1663.135	1890.887
	Random	Near	2486.178	58.116	2369.928	2602.428
		Far	1934.336	56.380	1821.559	2047.114

15. Condition * TestPeriod * Config * Target

Condition	TestPeriod	Config	Target	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Proximal	1	Repeated	Near	2694.512	78.089	2538.310	2850.713
			Far	2225.891	92.701	2040.461	2411.321
		Random	Near	2783.084	91.898	2599.261	2966.907
			Far	2326.442	91.263	2143.888	2508.995
	2	Repeated	Near	2406.828	68.320	2270.168	2543.489
			Far	1991.085	82.978	1825.106	2157.065
		Random	Near	2564.818	99.916	2364.956	2764.680
			Far	2092.932	92.665	1907.574	2278.289
	3	Repeated	Near	2264.408	67.743	2128.902	2399.915
			Far	1770.365	77.870	1614.602	1926.129
		Random	Near	2497.890	79.493	2338.879	2656.900
			Far	1883.187	77.119	1728.926	2037.448
Distal	1	Repeated	Near	2731.384	83.301	2564.758	2898.010
			Far	2299.551	98.888	2101.746	2497.356
		Random	Near	2890.401	98.031	2694.310	3086.492
			Far	2355.973	97.354	2161.236	2550.710
	2	Repeated	Near	2339.983	72.879	2194.203	2485.764
			Far	1988.963	88.515	1811.906	2166.020
		Random	Near	2695.110	106.584	2481.910	2908.311
			Far	2239.134	98.849	2041.406	2436.862
	3	Repeated	Near	2149.066	72.264	2004.516	2293.615
			Far	1783.657	83.067	1617.498	1949.816
		Random	Near	2474.467	84.799	2304.844	2644.089
			Far	1985.486	82.266	1820.930	2150.042

T-Test on the Contextual Cueing Effect for Near and Far Targets

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	NearRep	2432.5919	62	351.76130	44.67373
	NearRand	2648.6581	62	410.67330	52.15556
Pair 2	FarRep	2009.0055	62	401.65115	51.00975
	FarRand	2144.2015	62	378.99475	48.13238

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	NearRep - NearRand	-216.06613	310.90665	39.48518	-295.02163	-137.11062	-5.472	61	.000
Pair 2	FarRep - FarRand	-135.19597	314.21317	39.90511	-214.99117	-55.40076	-3.388	61	.001

T-Test on Random vs. Repeated Trials (for each type of trial)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	NearRepProximal	2455.2485	33	372.41403	64.82896
	NearRandProximal	2615.2630	33	436.50062	75.98501
Pair 2	FarRepProximal	1995.7791	33	396.94848	69.09986
	FarRandProximal	2100.8527	33	419.06297	72.94950
Pair 3	NearRepDistal	2406.8103	29	331.31397	61.52346
	NearRandDistal	2686.6593	29	383.22295	71.16272
Pair 4	FarRepDistal	2024.0562	29	413.44464	76.77474
	FarRandDistal	2193.5293	29	327.85249	60.88068

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	NearRepProximal – NearRandProximal	-160.01455	279.16790	48.59689	-259.00318	-61.02591	-3.293	32	.002
Pair 2	FarRepProximal – FarRandProximal	-105.07364	281.02972	48.92100	-204.72244	-5.42483	-2.148	32	.039
Pair 3	NearRepDistal – NearRandDistal	-279.84897	337.04973	62.58856	-408.05582	-151.64211	-4.471	28	.000
Pair 4	FarRepDistal - FarRandDistal	-169.47310	350.06238	65.00495	-302.62971	-36.31649	-2.607	28	.014

Appendix F: SPSS Output for Experiment 2 Egocentric Data (P-Near)

Three-way mixed-model ANOVA

Within-subject Factors:

- Test Period: 1 vs. 2 vs. 3
- Config: Repeated vs. Random

Between-subject Factors:

- Target: Near vs. Far

Dependent Variable:

- Reaction Time

Descriptive Statistics

	Target	Mean	Std. Deviation	N
Rep1	Near	2694.5118	462.48672	33
	Far	2299.5510	542.90931	29
	Total	2509.7721	535.70032	62
Rand1	Near	2783.0839	541.64705	33
	Far	2355.9731	464.15082	29
	Total	2583.3063	546.76716	62
Rep2	Near	2406.8285	407.39263	33
	Far	1988.9631	473.34355	29
	Total	2211.3753	483.83251	62
Rand2	Near	2564.8182	535.60959	33
	Far	2239.1341	627.31465	29
	Total	2412.4821	598.30348	62
Rep3	Near	2264.4082	423.17456	33
	Far	1783.6569	456.45196	29
	Total	2039.5406	498.05666	62
Rand3	Near	2497.8897	467.67376	33
	Far	1985.4859	425.51892	29
	Total	2258.2169	514.08940	62

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Sphericity Assumed	9989836.006	2	4994918.003	31.759	.000	.346
	Greenhouse-Geisser	9989836.006	1.942	5143214.633	31.759	.000	.346
	Huynh-Feldt	9989836.006	2.000	4994918.003	31.759	.000	.346
	Lower-bound	9989836.006	1.000	9989836.006	31.759	.000	.346
TestPeriod * Target	Sphericity Assumed	251439.664	2	125719.832	.799	.452	.013
	Greenhouse-Geisser	251439.664	1.942	129452.391	.799	.449	.013
	Huynh-Feldt	251439.664	2.000	125719.832	.799	.452	.013
	Lower-bound	251439.664	1.000	251439.664	.799	.375	.013
Error(TestPeriod)	Sphericity Assumed	18873059.170	120	157275.493			
	Greenhouse-Geisser	18873059.170	116.540	161944.924			
	Huynh-Feldt	18873059.170	120.000	157275.493			
	Lower-bound	18873059.170	60.000	314550.986			
Config	Sphericity Assumed	2513575.554	1	2513575.554	16.969	.000	.220
	Greenhouse-Geisser	2513575.554	1.000	2513575.554	16.969	.000	.220
	Huynh-Feldt	2513575.554	1.000	2513575.554	16.969	.000	.220
	Lower-bound	2513575.554	1.000	2513575.554	16.969	.000	.220
Config * Target	Sphericity Assumed	2071.835	1	2071.835	.014	.906	.000
	Greenhouse-Geisser	2071.835	1.000	2071.835	.014	.906	.000
	Huynh-Feldt	2071.835	1.000	2071.835	.014	.906	.000
	Lower-bound	2071.835	1.000	2071.835	.014	.906	.000
Error(Config)	Sphericity Assumed	8887695.082	60	148128.251			
	Greenhouse-Geisser	8887695.082	60.000	148128.251			
	Huynh-Feldt	8887695.082	60.000	148128.251			
	Lower-bound	8887695.082	60.000	148128.251			

TestPeriod * Config	Sphericity Assumed	396890.760	2	198445.380	1.973	.143	.032
	Greenhouse-Geisser	396890.760	1.838	215979.052	1.973	.148	.032
	Huynh-Feldt	396890.760	1.924	206230.719	1.973	.145	.032
	Lower-bound	396890.760	1.000	396890.760	1.973	.165	.032
TestPeriod * Config * Target	Sphericity Assumed	79218.437	2	39609.218	.394	.675	.007
	Greenhouse-Geisser	79218.437	1.838	43108.897	.394	.658	.007
	Huynh-Feldt	79218.437	1.924	41163.153	.394	.667	.007
	Lower-bound	79218.437	1.000	79218.437	.394	.533	.007
Error(TestPeriod*Config)	Sphericity Assumed	12068134.051	120	100567.784			
	Greenhouse-Geisser	12068134.051	110.258	109453.466			
	Huynh-Feldt	12068134.051	115.470	104513.224			
	Lower-bound	12068134.051	60.000	201135.568			

Tests of Within-Subjects Contrasts

Source	TestPeriod	Config	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Linear		9899456.688	1	9899456.688	62.752	.000	.511
	Quadratic		90379.318	1	90379.318	.576	.451	.010
TestPeriod * Target	Linear		112947.471	1	112947.471	.716	.401	.012
	Quadratic		138492.193	1	138492.193	.883	.351	.015
Error(TestPeriod)	Linear		9465317.827	60	157755.297			
	Quadratic		9407741.344	60	156795.689			
Config		Linear	2513575.554	1	2513575.554	16.969	.000	.220
Config * Target		Linear	2071.835	1	2071.835	.014	.906	.000
Error(Config)		Linear	8887695.082	60	148128.251			
TestPeriod * Config	Linear	Linear	325239.338	1	325239.338	4.001	.050	.063
	Quadratic	Linear	71651.421	1	71651.421	.598	.442	.010
TestPeriod * Config * Target	Linear	Linear	.955	1	.955	.000	.997	.000
	Quadratic	Linear	79217.482	1	79217.482	.661	.419	.011
Error(TestPeriod*Config)	Linear	Linear	4877496.218	60	81291.604			
	Quadratic	Linear	7190637.832	60	119843.964			

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1997401680.413	1	1997401680.413	2599.346	.000	.977
Target	16843548.490	1	16843548.490	21.920	.000	.268
Error	46105479.273	60	768424.655			

Estimated Marginal Means:

1. Target

Estimates

Target	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Near	2535.257	62.297	2410.644	2659.870
Far	2108.794	66.455	1975.865	2241.723

Pairwise Comparisons

(I) Target	(J) Target	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Near	Far	426.463*	91.089	.000	244.258	608.667
Far	Near	-426.463*	91.089	.000	-608.667	-244.258

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

2. TestPeriod

Estimates

TestPeriod	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2533.280	58.444	2416.375	2650.184
2	2299.936	55.976	2187.968	2411.904
3	2132.860	47.130	2038.585	2227.135

Pairwise Comparisons

(I) TestPeriod	(J) TestPeriod	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	233.344*	54.069	.000	125.190	341.498
	3	400.420*	50.548	.000	299.309	501.530
2	1	-233.344*	54.069	.000	-341.498	-125.190
	3	167.076*	46.512	.001	74.038	260.114
3	1	-400.420*	50.548	.000	-501.530	-299.309
	2	-167.076*	46.512	.001	-260.114	-74.038

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

3. Config

Estimates

Config	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Repeated	2239.653	49.900	2139.838	2339.469
Random	2404.397	49.581	2305.221	2503.574

Pairwise Comparisons

(I) Config	(J) Config	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Repeated	Random	-164.744*	39.993	.000	-244.742	-84.746
Random	Repeated	164.744*	39.993	.000	84.746	244.742

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

4. Target * TestPeriod

Target	TestPeriod	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Near	1	2738.798	79.941	2578.892	2898.704
	2	2485.823	76.565	2332.670	2638.977
	3	2381.149	64.466	2252.197	2510.101
Far	1	2327.762	85.276	2157.184	2498.340
	2	2114.049	81.675	1950.674	2277.423
	3	1884.571	68.769	1747.013	2022.130

5. Target * Config

Target	Config	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Near	Repeated	2455.249	68.255	2318.719	2591.780
	Random	2615.264	67.818	2479.607	2750.921
Far	Repeated	2024.057	72.810	1878.414	2169.700
	Random	2193.531	72.345	2048.820	2338.242

6. TestPeriod * Config

TestPeriod	Config	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	Repeated	2497.031	63.839	2369.334	2624.729
	Random	2569.529	64.518	2440.473	2698.584
2	Repeated	2197.896	55.921	2086.038	2309.754
	Random	2401.976	73.841	2254.273	2549.680
3	Repeated	2024.033	55.872	1912.272	2135.793
	Random	2241.688	57.078	2127.515	2355.860

7. Target * TestPeriod * Config

Target	TestPeriod	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Near	1	Repeated	2694.512	87.322	2519.843	2869.181
		Random	2783.084	88.250	2606.557	2959.611
	2	Repeated	2406.828	76.490	2253.825	2559.832
		Random	2564.818	101.002	2362.784	2766.852
	3	Repeated	2264.408	76.423	2111.539	2417.277
		Random	2497.890	78.073	2341.721	2654.059
Far	1	Repeated	2299.551	93.149	2113.225	2485.877
		Random	2355.973	94.140	2167.665	2544.281
	2	Repeated	1988.963	81.595	1825.749	2152.178
		Random	2239.134	107.743	2023.617	2454.651
	3	Repeated	1783.657	81.524	1620.585	1946.728
		Random	1985.486	83.283	1818.894	2152.077

T-Test for the Contextual Cueing Effect for Near and Far Targets

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RepNear	2455.2485	33	372.41403	64.82896
	RandNear	2615.2630	33	436.50062	75.98501
Pair 2	RepFar	2024.0562	29	413.44464	76.77474
	RandFar	2193.5293	29	327.85249	60.88068

Paired Samples Test

		Paired Differences Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	RepNear – RandNear	-160.01455	279.16790	48.59689	-259.00318	-61.02591	-3.293	32	.002
Pair 2	RepFar - RandFar	-169.47310	350.06238	65.00495	-302.62971	-36.31649	-2.607	28	.014

Appendix G: SPSS Output for Experiment 2 Egocentric Data (P-Far)

Three-way mixed-model ANOVA

Within-subject Factors:

- Test Period: 1 vs. 2 vs. 3
- Config: Repeated vs. Random

Between-subject Factor:

- Target: Near vs. Far

Dependent Variable:

- Reaction Time

Descriptive Statistics

	Target	Mean	Std. Deviation	N
Rep1	Near	2731.3841	432.15552	29
	Far	2225.8906	523.27511	33
	Total	2462.3311	542.24043	62
Rand1	Near	2890.4007	511.76387	29
	Far	2326.4418	571.70557	33
	Total	2590.2290	610.04736	62
Rep2	Near	2339.9834	374.68387	29
	Far	1991.0855	479.56185	33
	Total	2154.2797	464.63751	62
Rand2	Near	2695.1103	614.89537	29
	Far	2092.9318	432.40614	33
	Total	2374.5960	602.82257	62
Rep3	Near	2149.0655	346.20509	29
	Far	1770.3655	439.19269	33
	Total	1947.4994	438.74206	62
Rand3	Near	2474.4669	443.72600	29
	Far	1883.1870	457.77668	33
	Total	2159.7534	537.37874	62

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Sphericity Assumed	13945389.078	2	6972694.539	53.867	.000	.473
	Greenhouse-Geisser	13945389.078	1.966	7092956.960	53.867	.000	.473
	Huynh-Feldt	13945389.078	2.000	6972694.539	53.867	.000	.473
	Lower-bound	13945389.078	1.000	13945389.078	53.867	.000	.473
TestPeriod * Target	Sphericity Assumed	62423.546	2	31211.773	.241	.786	.004
	Greenhouse-Geisser	62423.546	1.966	31750.102	.241	.782	.004
	Huynh-Feldt	62423.546	2.000	31211.773	.241	.786	.004
	Lower-bound	62423.546	1.000	62423.546	.241	.625	.004
Error(TestPeriod)	Sphericity Assumed	15533189.825	120	129443.249			
	Greenhouse-Geisser	15533189.825	117.965	131675.837			
	Huynh-Feldt	15533189.825	120.000	129443.249			
	Lower-bound	15533189.825	60.000	258886.497			
Config	Sphericity Assumed	3430484.086	1	3430484.086	24.039	.000	.286
	Greenhouse-Geisser	3430484.086	1.000	3430484.086	24.039	.000	.286
	Huynh-Feldt	3430484.086	1.000	3430484.086	24.039	.000	.286
	Lower-bound	3430484.086	1.000	3430484.086	24.039	.000	.286
Config * Target	Sphericity Assumed	707247.383	1	707247.383	4.956	.030	.076
	Greenhouse-Geisser	707247.383	1.000	707247.383	4.956	.030	.076
	Huynh-Feldt	707247.383	1.000	707247.383	4.956	.030	.076
	Lower-bound	707247.383	1.000	707247.383	4.956	.030	.076
Error(Config)	Sphericity Assumed	8562242.148	60	142704.036			
	Greenhouse-Geisser	8562242.148	60.000	142704.036			
	Huynh-Feldt	8562242.148	60.000	142704.036			
	Lower-bound	8562242.148	60.000	142704.036			

TestPeriod * Config	Sphericity Assumed	183265.916	2	91632.958	.893	.412	.015
	Greenhouse-Geisser	183265.916	1.789	102450.566	.893	.402	.015
	Huynh-Feldt	183265.916	1.871	97956.264	.893	.406	.015
	Lower-bound	183265.916	1.000	183265.916	.893	.349	.015
TestPeriod * Config * Target	Sphericity Assumed	163000.744	2	81500.372	.794	.454	.013
	Greenhouse-Geisser	163000.744	1.789	91121.790	.794	.442	.013
	Huynh-Feldt	163000.744	1.871	87124.459	.794	.447	.013
	Lower-bound	163000.744	1.000	163000.744	.794	.376	.013
Error(TestPeriod*Config)	Sphericity Assumed	12315815.135	120	102631.793			
	Greenhouse-Geisser	12315815.135	107.329	114747.853			
	Huynh-Feldt	12315815.135	112.254	109714.094			
	Lower-bound	12315815.135	60.000	205263.586			

Tests of Within-Subjects Contrasts

Source	TestPeriod	Config	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TestPeriod	Linear		13887042.354	1	13887042.354	115.240	.000	.658
	Quadratic		58346.724	1	58346.724	.422	.519	.007
TestPeriod * Target	Linear		38182.606	1	38182.606	.317	.576	.005
	Quadratic		24240.939	1	24240.939	.175	.677	.003
Error(TestPeriod)	Linear		7230337.566	60	120505.626			
	Quadratic		8302852.259	60	138380.871			
Config		Linear	3430484.086	1	3430484.086	24.039	.000	.286
Config * Target		Linear	707247.383	1	707247.383	4.956	.030	.076
Error(Config)		Linear	8562242.148	60	142704.036			
TestPeriod * Config	Linear	Linear	123166.115	1	123166.115	1.463	.231	.024
	Quadratic	Linear	60099.802	1	60099.802	.496	.484	.008
TestPeriod * Config * Target	Linear	Linear	91653.151	1	91653.151	1.089	.301	.018
	Quadratic	Linear	71347.593	1	71347.593	.589	.446	.010
Error(TestPeriod*Config)	Linear	Linear	5051908.817	60	84198.480			
	Quadratic	Linear	7263906.318	60	121065.105			

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1955475576.076	1	1955475576.076	2608.459	.000	.978
Target	23006958.030	1	23006958.030	30.690	.000	.338
Error	44980022.535	60	749667.042			

Estimated Marginal Means

1. Target

Estimates

Target	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Near	2546.735	65.639	2415.438	2678.032
Far	2048.317	61.532	1925.235	2171.400

Pairwise Comparisons

(I) Target	(J) Target	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Near	Far	498.418*	89.970	.000	318.451	678.385
Far	Near	-498.418*	89.970	.000	-678.385	-318.451

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

2. TestPeriod

Estimates

TestPeriod	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2543.529	55.855	2431.802	2655.256
2	2279.778	52.489	2174.785	2384.771
3	2069.271	47.881	1973.494	2165.048

Pairwise Comparisons

(I) TestPeriod	(J) TestPeriod	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	263.752*	48.700	.000	166.336	361.167
	3	474.258*	44.179	.000	385.887	562.629
2	1	-263.752*	48.700	.000	-361.167	-166.336
	3	210.507*	44.340	.000	121.813	299.200
3	1	-474.258*	44.179	.000	-562.629	-385.887
	2	-210.507*	44.340	.000	-299.200	-121.813

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

3. Config

Estimates

Config	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Repeated	2201.296	46.806	2107.671	2294.921
Random	2393.756	51.254	2291.233	2496.280

Pairwise Comparisons

(I) Config	(J) Config	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Repeated	Random	-192.461*	39.254	.000	-270.980	-113.941
Random	Repeated	192.461*	39.254	.000	113.941	270.980

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

4. Target * TestPeriod

Target	TestPeriod	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Near	1	2810.892	81.499	2647.870	2973.915
	2	2517.547	76.587	2364.349	2670.744
	3	2311.766	69.865	2172.016	2451.517
Far	1	2276.166	76.400	2123.343	2428.990
	2	2042.009	71.796	1898.396	2185.622
	3	1826.776	65.494	1695.769	1957.783

5. Target * Config

Target	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Near	Repeated	2406.811	68.295	2270.201	2543.421
	Random	2686.659	74.786	2537.065	2836.253
Far	Repeated	1995.781	64.022	1867.717	2123.844
	Random	2100.854	70.107	1960.618	2241.089

6. TestPeriod * Config

TestPeriod	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	Repeated	2478.637	61.456	2355.707	2601.568
	Random	2608.421	69.303	2469.795	2747.048
2	Repeated	2165.534	55.206	2055.106	2275.963
	Random	2394.021	66.880	2260.242	2527.800
3	Repeated	1959.715	50.716	1858.268	2061.163
	Random	2178.827	57.432	2063.947	2293.707

7. Target * TestPeriod * Config

Target	TestPeriod	Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Near	1	Repeated	2731.384	89.672	2552.014	2910.754
		Random	2890.401	101.121	2688.128	3092.673
	2	Repeated	2339.983	80.552	2178.855	2501.111
		Random	2695.110	97.586	2499.910	2890.310
	3	Repeated	2149.066	74.001	2001.041	2297.090
		Random	2474.467	83.800	2306.843	2642.091
Far	1	Repeated	2225.891	84.062	2057.742	2394.039
		Random	2326.442	94.795	2136.824	2516.060
	2	Repeated	1991.085	75.512	1840.038	2142.133
		Random	2092.932	91.480	1909.944	2275.920
	3	Repeated	1770.365	69.371	1631.602	1909.129
		Random	1883.187	78.557	1726.050	2040.324

T-Test on the Contextual Cueing Effect for Near and Far Targets

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RepN	2406.8103	29	331.31397	61.52346
	RandN	2686.6593	29	383.22295	71.16272
Pair 2	RepF	1995.7791	33	396.94848	69.09986
	RandF	2100.8527	33	419.06297	72.94950

Paired Samples Test

		Paired Differences Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	RepNear – RandNear	-279.84897	337.04973	62.58856	-408.05582	-151.64211	-4.471	28	.000
Pair 2	RepFar – RandFar	-105.07364	281.02972	48.92100	-204.72244	-5.42483	-2.148	32	.039

Appendix H: SPSS Output for Experiment 2 Awareness Data

Two-way mixed-model ANOVA of Awareness Performance (averaged across target position)

Within-subject Factor:

- Config: Repeated vs. Random

Between-subject Factor:

- Condition: Proximal vs. Distal

Dependent Variable:

- Degrees of angle of target detection error

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
AllRepError	Proximal	27.5348	6.16182	33
	Distal	25.7590	6.16281	29
	Total	26.7042	6.17651	62
AllRandError	Proximal	29.1773	5.90299	33
	Distal	26.9066	5.97123	29
	Total	28.1152	5.99589	62

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Config	Sphericity Assumed	60.076	1	60.076	2.703	.105	.043
	Greenhouse-Geisser	60.076	1.000	60.076	2.703	.105	.043
	Huynh-Feldt	60.076	1.000	60.076	2.703	.105	.043
	Lower-bound	60.076	1.000	60.076	2.703	.105	.043
Config * Condition	Sphericity Assumed	1.890	1	1.890	.085	.772	.001
	Greenhouse-Geisser	1.890	1.000	1.890	.085	.772	.001
	Huynh-Feldt	1.890	1.000	1.890	.085	.772	.001
	Lower-bound	1.890	1.000	1.890	.085	.772	.001
Error(Config)	Sphericity Assumed	1333.575	60	22.226			
	Greenhouse-Geisser	1333.575	60.000	22.226			
	Huynh-Feldt	1333.575	60.000	22.226			
	Lower-bound	1333.575	60.000	22.226			

Tests of Within-Subjects Contrasts

Source	Config	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Config	Linear	60.076	1	60.076	2.703	.105	.043
Config * Condition	Linear	1.890	1	1.890	.085	.772	.001
Error(Config)	Linear	1333.575	60	22.226			

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	92330.957	1	92330.957	1811.443	.000	.968
Condition	126.378	1	126.378	2.479	.121	.040
Error	3058.257	60	50.971			

Estimated Marginal Means:

1. Condition

Estimates

Condition	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Proximal	28.356	.879	26.598	30.114
Distal	26.333	.937	24.458	28.208

Pairwise Comparisons

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Proximal	Distal	2.023	1.285	.121	-.547	4.594
Distal	Proximal	-2.023	1.285	.121	-4.594	.547

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

2. Config

Estimates

Config	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Repeated	26.647	.784	25.078	28.216
Random	28.042	.755	26.531	29.553

Pairwise Comparisons

(I) Config	(J) Config	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Repeated	Random	-1.395	.849	.105	-3.092	.302
Random	Repeated	1.395	.849	.105	-.302	3.092

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

3. Condition * Config

				95% Confidence Interval	
Condition	Config	Mean	Std. Error	Lower Bound	Upper Bound
Proximal	Repeated	27.535	1.073	25.389	29.681
	Random	29.177	1.033	27.111	31.244
Distal	Repeated	25.759	1.144	23.470	28.048
	Random	26.907	1.102	24.702	29.111

Appendix I: SPSS Output for Experiment 2 Awareness Correlation

Correlation between contextual cueing magnitude and awareness performance

Contextual Cueing Average (CCavg) = Random RT – Repeated RT

Awareness = Random angle of error – Repeated angle of error (Positive scores indicate more awareness)

Correlations

		Awareness	CCavg
Awareness	Pearson Correlation	1	.167
	Sig. (2-tailed)		.194
	N	62	62
CCavg	Pearson Correlation	.167	1
	Sig. (2-tailed)	.194	
	N	62	62