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How Enduring is Global Precedence?

Jong Lee
University of South Florida

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by

Han Lee

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Major Professor: Thomas Sanocki, Ph.D.
Chad Dube, Ph.D.
Geoffrey Potts, Ph.D.

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ABSTRACT

There is a set of visual processing advantages for holistic or global information over detailed or local information; these advantages are known as global precedence (Navon, 1977). Currently, there are inconsistent results about whether selective attention can reduce global precedence. Our studies look into Lamb et al. (1998)'s claim about selective attention's inability to reduce global precedence. We reassess Lamb and colleagues' claim by examining whether consecutively repeated tasks strengthen selective attention and reduce interference or facilitation from irrelevant information. Our studies utilized a series of trials, or runs, to present multiple consecutively repeated tasks. Before each run, participants were directed to a level (global or local) and target (A, E, G, K, U) and tasked to confirm or deny the presence of a target at a focused level. Inside each trial, participants were briefly shown one hierarchical letter - a large letter (one of the target letters) made up of small letters (one of the same five) to represent global and local levels respectively. The focused level always contained the target while the irrelevant level switched between congruent (e.g., giant A made of small A's) and incongruent (e.g., giant E made of small A's) information at specific points in a run (trials two or six). Response times (RT) to complete the task were analyzed. Our primary concern was the influence of the irrelevant level (i.e., interference or facilitation) during globally or locally focused runs (i.e., elevation in RT for an incongruent stimulus relative to congruent stimulus). Experiment 1 showed that local interference (i.e., influence of an incongruent local level during global searches) decreased from multiple consecutively repeated tasks but global interference was still large during local searches. Experiment 2 showed no local facilitation and an insignificant reduction in global facilitation. A fit to the power-function speed-up model used in Logan (1988) confirmed that participants switched from a general algorithm to instance-based strategies in our paradigm.

INTRODUCTION

People must process information in the visual field to know what they are seeing. But visual processing research has complexities. One such complexity is understanding the order in which the visual system processes items and their parts. Does the visual system process an item first as a whole or by its parts? One hypothesis is that the visual system processes items as a whole and then by its parts (Navon, 1977). This extends from the global precedence effect, a robust phenomenon characterized by faster encoding and asymmetrical interference for holistic items during visual processing. Studies have examined global precedence together with cognitive mechanisms such as selective attention to investigate the relationship between cognitive mechanisms and visual processing (e.g., Hoffman, 1980; Hughes et al., 1984; Kinchla et al., 1983; Kinchla & Wolfe,1979; Lamb et al., 1998; Miller, 1981; Paquet & Merikle, 1988; Pomerantz, 1983; Ward, 1982; Weinbach & Henik, 2014). Currently, there are inconsistent results about whether cognitive mechanisms can overcome global precedence (e.g., Hoffman, 1980; Kinchla et al., 1983; Miller, 1981; Ward, 1982) or fail to reduce global precedence (e.g., Hughes et al., 1984; Lamb et al., 1998; Navon, 1981).

The present study investigates this inconsistency by strengthening selective attention and seeing if this enhanced cognitive mechanism can overcome global precedence.

ATTENTION

Attention is a finite mental resource that increases the quality of and focus on selected stimuli in the environment. A person's intentions or each stimulus' properties determine the distribution of attention. The visual system uses attention to increase perception (Hoffman, 1980; Carrasco & Barbot, 2014; Ward, 1982; Yeshurun & Carrasco, 1998). This system focuses attention in a region inside the visual field known as the attentional window; items outside of this window have a lower potential in attracting attention (Belopolsky et al., 2007; Belopolsky & Theeuwes, 2010; Notebaert et al., 2013; Theeuwes, 1991, 2004; Yantis & Jonides, 1990). This attentional window can enlarge or shrink in size to enable better visual processing (Belopolsky & Theeuwes, 2010; Notebaert et al., 2013).

Attention can be utilized by both cognitive and non-cognitive mechanisms to perform tasks. In this paper, cognitive mechanisms are defined as goal- or task-driven mechanisms that allow a person to voluntarily control resource allocation and allocates resources based on a person's intent. Cognitive mechanisms often allocate attention to goal-oriented tasks or targets (e.g., paying attention to a traffic light). This includes readjusting the attentional window and inhibiting the processing of irrelevant information (Belopolsky et al., 2007; Chun & Wolfe, 2001; Eriksen & James, 1986; Eriksen & Yeh, 1985; Gaspelin & Luck, 2017; Neill, 1977; Notebaert et al., 2013; Verschooren et al., 2019). Non-cognitive mechanisms are mechanisms that are outside of a person's control and often stimulus-driven; these mechanisms allocate resources based on stimulus properties such as size, color or shape regardless of a person's intent. When these mechanisms are in control, stimulus properties dictate resource allocation instead of tasks or goals. Non-cognitive mechanisms enable items inside the attentional window to capture attention (Gaspelin & Luck, 2017). One such example is involuntary attentional shifts between cars on the highway. This captured attention focuses (i.e., enlarge or shrink) the window as the visual system progressively encodes each item or feature. Saliency can influence this captured attention (Belopolsky et al., 2007; Gaspelin & Luck, 2017; Theeuwes, 1994).

Saliency

For our purposes, saliency is broadly defined as an item's ability to attract attention (Schubo, 2009) and initiates visual processing for that item based on the item's features and non-cognitive mechanisms. Saliency is a complex concept, and will be explained in relation to specific tasks in later sections. In general, an item's salient properties can influence the strength and order of attentional allocation given to the item during attentional capture; a highly salient item will capture more attention than an item with low saliency (Belopolsky & Theeuwes, 2010; Gaspelin & Luck, 2017; Theeuwes, 1991, 1993, 1992, 1994). When control over resource allocation is not prioritized, saliency dictates the focusing of the attentional window such that the most salient item captures attention (Gaspelin & Luck, 2017; Theeuwes, 1992, 1994); this will involuntarily adjust the attentional window accordingly using non-cognitive mechanisms.

There are various different types of saliency that vary in strength. Saliency can be compared between categories (e.g., visual, auditory or semantics) as well as within a category. Semantic meaning can have stronger saliency than some visual perception features such as color (Stroop, 1935) and larger items have stronger saliency than smaller items (Simon et al., 2009; Sripati & Olsen, 2009). The former example compares saliency between two categories (semantic meaning vs. visual perception) while the latter compares saliency within one category (size).[1] Past studies have shown that selective attention can sometimes deploy cognitive control (i.e., control over resource allocation) to reorganize the processing order set by saliency (e.g., Bacon & Egeth, 1994; Dreisbach & Haider, 2008; Folk et al., 1992; Gaspelin & Luck, 2017). However, the setting for these occurrences and the limitations of selective attention have been debated amongst the attention literature.

Selective Attention

Selective attention is a cognitive mechanism that controls the deployment and focus of attention by directing attention to specific items and suppressing irrelevant information (see Driver, 2001 for review; Stevens & Bavelier, 2011). For example, the visual system may favor attending to highway signs when looking for the correct exit.

A function of selective attention is allocating attention or reallocating captured attention to relevant targets or goals by manually shifting the attentional window between items (Belopolsky et al., 2007; Chun & Wolfe, 2001; Eriksen & James, 1986; Eriksen & Yeh, 1985; Notebaert et al., 2013; Verschooren et al., 2019). One example is searching for a target such as your car in a parking lot and shifting attention between cars with similar features. Selective attention can also focus the attentional window to details within an item (Wilkinson et al., 2001). During a visual search for your car, you may start with a car's model type and then focus on the

[1] It is important to clarify that comparisons between and within categories are complex and hierarchical because multiple different categories can be embedded within one another. For example, comparison between red items and large items are comparisons within one category (visual perception). However, these features are also categorically different (color and size respectively) and comparisons can go further within each category (e.g., blue vs. red or large vs. small). This section is simply used to note some of the different ways that saliency can be compared.

license plates. Similarly, when looking for your friend's flamingo-decorated house, you may start with the type of house and then proceed to look for flamingo decorations around the house.

Selective attention also reduces the influence of salient irrelevant information (Kim & Cave, 1999; Verschooren et al., 2019) by either maintaining focus on goal-oriented tasks and targets (Reisenauer & Dreisbach, 2014) or inhibiting responses to irrelevant information (Neill, 1977; Gaspelin & Luck, 2017). For example, you may direct your attention to looking for your custom license plate when searching for your car or ignore non-flamingo decorations to identify your friend's house. However, selective attention's efficiency depends on the level of saliency such that highly salient items require strong selective attention to reduce their influence (Bacon & Egeth, 1994; Folk et al., 1994; Theeuwes, 1992). Additionally, the intent to ignore an item can occasionally fail to prevent involuntary attentional attraction to that item (Remington et al., 1992; Stoffer, 1994). In summary, selective attention can control attentional focus with its ability to shift, set or maintain a specific attentional window; but strong selective attention is needed to reduce the influence of highly salient items or features. Currently, a major portion of the attention literature is devoted to determining the limitations of selective attention's abilities. This is especially true for selective attention's ability to reduce the processing of salient irrelevant information.

Attentional Focus

Attentional focus is important; performance can improve when the visual system allocates attention to an item (e.g., faster processing; Eriksen & Yeh, 1985; Gaspelin & Luck, 2017; Schneider & Shiffrin, 1977; better perception; Barbot & Carrasco, 2017; Barbot et al., 2017; Carrasco & Barbot, 2014; Yeshurun & Carrasco, 1998). From this, attention is likely to be an important component in visual perception. There is an order in which the visual system registers and processes items in the visual field (Navon, 1977, 1981) and the encoding speed for each item determines this order (Kinchla et al., 1983; Navon, 1981; Ward, 1982).

Attentional feedback can occur during visual recognition or processing of items where this system allocates or reallocates attention to prioritized items (Ling et al., 2014). Attention can influence the recognition or perception for an item such that the deployment of attention, or additional attention, enhances the encoding speed for the attended item compared to the non-attended item (Hoffman, 1980). The enhanced encoding speed leads to faster perception of - and responses to - the attended item (Hoffman, 1980). In short, attention facilitates the perception for an item which speeds up the item's recognition and responses to these items compared to their non-attended or less attended counterparts.

GLOBAL PRECEDENCE

One goal for visual perception research is determining the order of information processing. Gestalt psychology suggests that the visual system processes holistic information before more detailed information. Navon (1977) provides support for this idea by evaluating RTs to hierarchical letters (see Figure 1). Navon (1977)'s results show that objects can have at least two different and separate visual levels which the visual system perceives at different times. The findings show that the visual system encodes and perceives the features at the holistic or global level faster in time than the features at the detailed or local level. Additionally, Navon (1977) found that the global level can slow down or interfere with the encoding of the features at the local level. These effects have been termed global precedence. Based on his research with hierarchical letters, Navon (1977) argues that there is a hierarchical structure within visual objects as well as the visual representation of these objects.

Structurally, these letters present two distinctly different levels for visual processing: global and local. The global level refers to the grouped or large letter and the smaller letters express the local level (Kimchi, 1992; Navon, 1977,1981). Principally, the global level has the broadly defined item created from grouping other, often smaller, items or details. The local level contains the individual items that create the larger or broadly defined item. Global precedence causes local letters to lose their individual properties and groups them together to create the global letter (Kimchi, 1992).

Studies have used hierarchical letters to show that the visual system forms the visual representation of these levels over time (e.g., Kinchla & Wolfe, 1979; Navon, 1977; Paquet & Merikle, 1988; Sripati & Olsen, 2009). It may be that the order of visual representation depends on the order of level perception (see figure 2); the visual representation of a hierarchical letter starts with the first perceived level's features followed by the next perceived level's features. This order of level perception depends on the time course of each level's encoding process; shorter time courses lead to earlier encoding and perception of the level. Encoding speed determines the length of this time course. Therefore, the order of visual representation for a hierarchical letter ultimately depends on the encoding speed for each level. This order of visual representation for levels within a hierarchical letter is similar to the order of visual representation for items in the visual field; items that are prioritized (i.e., have faster encoding speeds) are visually represented before other, less prioritized, items.[2]

Global precedence implies that baseline order of visual representation for hierarchical letters is biased. This bias is that the global level forms the initial visual representation of hierarchical letters, followed by the local level (Navon, 1977, 1981).

Global precedence arises from two advantages for the global level during visual processing, global dominance and global interference. Global dominance is when the visual system perceives features at the global level before the features at the local level (Navon, 1977, 1981), causing faster responses to the global level (Navon, 1977; Poirel et al., 2008). This may occur because features at the global level have faster encoding speeds than features at the local level**.** Global interference is an asymmetrical interference effect that occurs with letters that are

[2] It is important to note that the encoding for both levels occur concurrently. However, the visual system completes the encoding for the global level before the local level because the encoding speed for the global level is faster than the local level.

incongruent between levels (e.g., giant ‘A’ made from small ‘E’; Navon, 1977, 1981). This is a separate effect that depends on the relation between global and local levels and the ability to inhibit or promote one of the levels.

When congruent (e.g., giant ‘A’ made from small ‘A’s), the two levels can facilitate the encoding of their counterpart level because there is no conflicting information to process (Hoffman, 1980). For example, determining the presence of the letter ‘A’ at the local level is easier when the global level forms the letter ‘A’. However, incongruencies cause features at the global level to heavily interfere with the encoding of features at the local level (Hoffman, 1980; Navon, 1977; Poirel et al., 2008); the visual system must process and resolve conflicting information, reducing the ability to properly and quickly respond to the local level (Dreisbach & Haider, 2009; Hoffman, 1980). It is difficult to determine the presence of the letter ‘A’ at the local level when the global level forms the letter ‘E’. Contrastingly, features at the local level cause less interference with the encoding of features at the global level (Navon, 1977; Paquet & Merikle, 1988; Poirel et al., 2008). The identity of the local letter barely affects the difficulty of determining the presence of the letter ‘A’ at the global level. These two advantages (global dominance, global interference) arise from a biased order of visual processing where the visual recognition of item features is likely to favor and start at the global level and progress toward the local level.

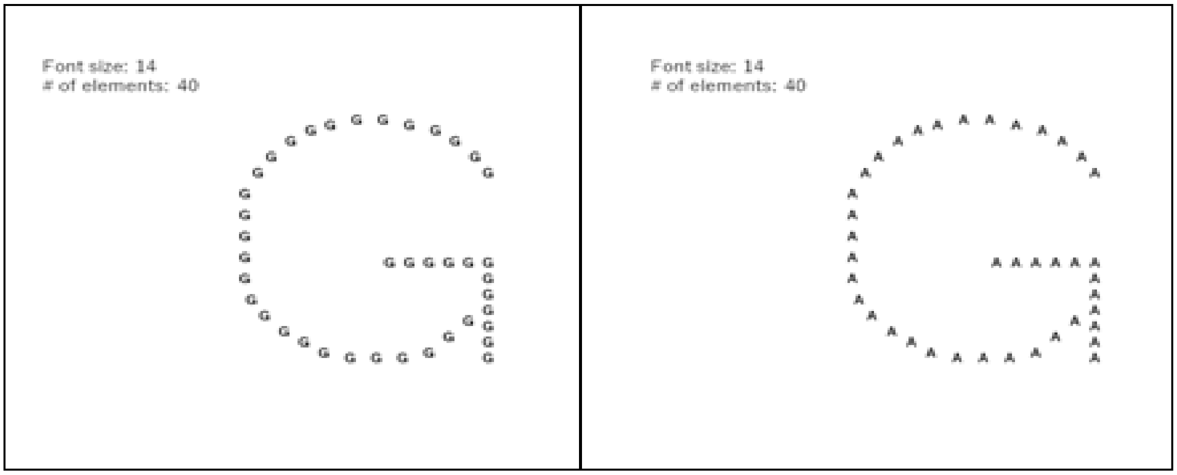

Figure 1. Hierarchical letters. Congruent global “G” and local “G” (left), Incongruent global “G” and local “A”

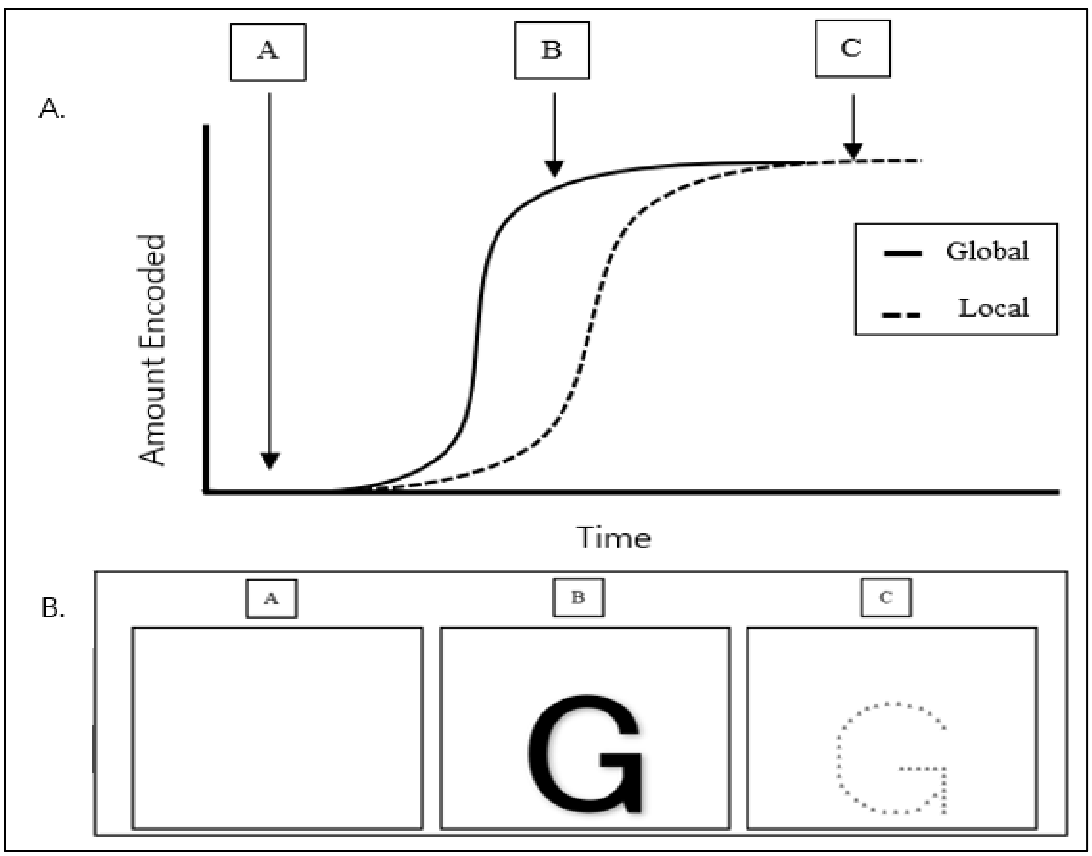

Figure 2. Theoretical model and visual representation of hierarchical letter processing. Model of the time course for the encoding process of a hierarchical letter (A); Visual representation of a hierarchical letter “G” over time (B).

GLOBAL PRECEDENCE AND ATTENTION

The cause of global precedence remains unclear. However, one explanation that fits existing data is that the advantages for the global level exists due to its built-in superior saliency. The global level is a large item while the local level is a small detail (e.g., the global house vs. the local bricks); this size difference indicates that the global level has more salient features, especially for hierarchical letters (Navon, 1981; Sripati & Olsen, 2009). More precisely, the global level generally has clearer and more optimal absolute size and visual angle than the local level (Kinchla & Wolfe, 1979). Therefore, acuity should be better for the global level than the local level. Furthermore, there is a disproportionate number of elements between the global and local levels. Inside a hierarchical letter, there are multiple local elements while there is only one global element. Although all the local letters in the hierarchical letter are identical, the local level is susceptible to crowding which makes it harder to perceive the local level (Whitney & Levi, 2011). These differences in level feature give the global level inherent visual advantages over the local level. Local precedence can be manufactured by manipulating saliency (e.g., adjusting features such as clarity) to favor the local level (Mevorach et al., 2006; Weinbach & Henik, 2014) but the global level frequently has more naturally occurring salient features for visual processing (see Kimchi, 1992 for review). This enables global precedence to occur more regularly than local precedence. Therefore, the global level often receives an advantage (e.g., faster or earlier encoding, asymmetrical interference) during visual processing.

Encoding Speed

Interestingly, encoding speeds for the global and local levels are equal when attentional influences are minimized (Hoffman, 1980). Hoffman (1980) utilized a method where participants searched for targets in one of three possible conditions: global, local, or either level. The either level conditions created divided attention and Hoffman (1980) found that participants are equally fast at locating the target at either level in this condition. For incongruent stimuli conditions, responses were faster in the specific level focus conditions (both global and local) than in the divided attention condition.

Studies have also shown that visual processing for each level start at the same time and occurs in parallel (e.g., Miller, 1981; Shedden & Reid, 2001). Therefore, it is possible that Navon and others' observation of saliency's advantage for the global level requires attentional allocation.

Saliency and Attention

In a feedback loop, the strong saliency of the global level captures and allocates more attention to the global level than the local level through the use of non-cognitive mechanisms. This captured attention increases the encoding speed for the global level more than the encoding speed for the local level (Hoffman, 1980). In doing so, the captured attention directly enhances the perception of the features at the global level. Therefore, one potential explanation for global precedence is that saliency captures more attention for the global level thereby providing this level an attentional advantage. Thus, the order of visual processing occurs from the most salient (i.e., global) level down to the least salient (i.e., local) level.

The present view is that saliency itself may not directly increase encoding speeds but saliency can be a driving component for an item to capture attention. During scene or item recognition, an unbiased baseline visual processing has equal encoding speeds and encoding time courses for all items in the visual field (Hoffman, 1980). However, an attentional feedback occurs where attention is allocated to items in the attentional window thereby boosting the encoding speed for each item. One possibility is that, saliency affects this feedback, here forth known as the saliency-feedback hypothesis. An item's salient property captures and allocates involuntary attention to that item.

Global precedence coincides with this notion. Because the salient global level captures more attention than the local level, the visual system encodes the global level faster than the local level and causes an earlier or faster visual representation of the global level (global dominance). With an incongruent global level, saliency attracts attention to process conflicting information which can disrupt the ability to process and respond to the local level (global interference).[3] Therefore, saliency provides captured attention for the global level. Global precedence is likely to occur directly from the attention given to the global level; but the global level's superior saliency is responsible for this captured attention.

[3] It is currently debated whether interference occurs during encoding, decision-making or response processes. Our current designs do not look at which process causes interference and therefore provide limited information in identifying when interference occurs.

CURRENT RESEARCH

The importance of global precedence research is its exploration of visual perception with objects that have multiple visual levels.

A critical issue is the extent to which voluntary attentional control (i.e., selective attention) can affect visual perception and global precedence. As previously discussed, voluntary attentional control can weaken the influence of salient properties (Kim & Cave, 1999; Verschooren et al., 2019), but some strong salient items or features can overrule attentional control (Theeuwes, 2004). Thus, the question becomes whether cognitive mechanisms such as selective attention are strong enough to overcome the global level's salient features or if the global level is too salient to overcome with attentional control.

Currently, the answer remains unclear. Some studies have found that global precedence can occur even with cognitive mechanisms directing attention to the local level (e.g., Navon, 1977; Paquet & Merikle, 1988) and have argued that selective attention has minimal influence on global precedence (e.g., Hubner, 2000; Lamb et al., 1998). Other studies have found that cognitive mechanisms can mitigate global precedence (e.g., Hoffman, 1980; Kinchla et al., 1983; Ward, 1982). Global precedence literature uses repeated exposure tactics to explore this issue (Hubner, 2000; Lamb et al., 1998; Ward, 1982).

REPEATED EXPOSURE

Repeated exposure tactics can involve sequential presentations of similar items (e.g., a picture of a car followed by another picture of a car). Global precedence research utilizes repeated exposure tactics by presenting hierarchical letters sequentially (Hubner, 2000; Lamb et al., 1998; Ward, 1982). Ward (1982) found that these tactics can reduce global precedence for subsequent hierarchical letters when the target is repeatedly shown at one level. Results provide evidence that shrinking the attentional window to the local level reduces the global level's saliency for subsequent hierarchical letters. However, saliency still influences the perception and hierarchical structure of the first item. If the global level is the most salient level, the visual system will attend and process the features at the global level before the features at the local level for the first stimulus; the visual system then focuses on the last attended level (i.e., local level) for the following stimulus unless otherwise directed (Ward, 1982).

Repeated exposure tactics show that previous exposures can influence subsequent exposures (Hubner, 2000; Lamb et al., 1998; Ward, 1982). This is known as the level-readiness effect or level-repetition effect within the global precedence literature (Lamb et al., 1998; Ward, 1982). The level-repetition effect lessens global precedence during attempts to process features at the local level (Hubner, 2000; Lamb et al., 1998; Ward, 1982). Previous exposures adjust the attentional window for attentional allocation and reduces saliency. An important assumption of this explanation is that previous exposures prepare the visual system by presetting the attentional window for following exposures. However, it is currently unknown whether cognitive mechanisms (i.e., selective attention) or non-cognitive mechanisms are producing the level-repetition effect (Hubner, 2000; Lamb et al., 1998; Ward, 1982). Lamb et al. (1998) uses the repeated exposure tactic to address this issue.

LAMB ET AL. (1998)

Lamb et al. (1998) proposed the mechanism-activation hypothesis as a possible account of the level-repetition effect instead of cognitive mechanisms. The mechanism-activation hypothesis states that the visual representation of a specific level activates the respective level-specific neural mechanism (Lamb et al., 1998). The recently activated mechanisms facilitate the visual representation of the following item or feature. Lamb et al. (1998) suggests that the mechanism-activation hypothesis is consistent with the idea that non-cognitive mechanisms are the cause for the level-repetition effect (see Lamb et al., 1998 for more detail).

Lamb et al. (1998)'s design involved participants identifying which target (H or S) was presented at a specified level in a stimulus. Lamb et al. (1998) used repeated exposure tactics and manipulated the predictability of which level would contain the target. Predictability tests whether cognitive or non-cognitive mechanisms are utilized during repeated exposures to produce the level-repetition effect. To do this, Lamb et al. (1998) created three different blocks of trials: random, alternating and constant. Each block had sixty-four trials. For the random block, the target level varied randomly and participants did not know which level contained the target, reducing the predictability of the target level. In doing so, participants could not voluntarily "preset" their attention to either level for visual advantages.

In the alternating blocks, participants knew that the target would alternate between levels (e.g., target would be at the global level for the first stimulus and then the local level in the next stimulus), producing a high predictability. This block allowed participants to voluntarily preset their attentional window using selective attention while preventing the activation of level-specific neural mechanisms to influence results.

The constant blocks had participants know that the target level remained the same throughout the entire block (e.g., target is always at the local level), producing a high predictability of the target level comparable to the alternating block. This allowed for an advantage for the directed level, similar to past repeated exposure studies (e.g., Ward, 1982).

Results showed that the alternating condition had the slowest performance. Participants performed no better and sometimes worse in this condition than the random condition despite knowing where to set their attentional window.[4] Participants could preset their attention and shrink or widen the attentional window as needed; however, selective attention failed to effectively preset the attentional window, leading to slower responses. Contrastingly, the constant condition had the fastest performance. The main difference between these two conditions is that the constant condition allowed for the non-cognitive activation of level-specific mechanisms while the alternating condition did not. Although selective attention may have been utilized in both conditions, only the constant condition showed the level-repetition effect. This performance difference between the two conditions supports the mechanism-activation hypothesis. From these results, Lamb et al. (1998) proposes that the activation of level-specific mechanisms is likely to be the cause of the level-repetition effect instead of selective attention

[4] Lamb et al. (1998) also looked at the random condition data after collapsing it into two categories; Rr (random-repeating) contained performance data from random trials that had targets presented at the same level as the previous trial, and Rc (random-changed) contained performance data from trials that had targets presented at a different level from the previous trial. Performance for Rr was reliably faster than performance for Rc.

presetting the attentional window. This provides support that cognitive mechanisms have little influence on reducing global precedence for hierarchical letters.

Lamb et al. (1998) performed a second experiment to examine if the level-repetition effect increased gradually with each consecutive repetition. This experiment was similar to the first but each block had eight trials and RTs were examined for each trial within the block. Interestingly, results showed that the level-repetition effect increased (i.e., faster RTs) with each consecutive repetition for both globally focused and locally focused blocks.

FACTORS INVOLVED WITH SELECTIVE ATTENTION

Lamb et al. (1998) concluded that presetting the attentional window – with selective attention - has little to no effect on visual perception for hierarchical letters. However, there are several variables that need to be addressed before making this claim. For one, Lamb et al. (1998)'s design may not entirely measure selective attention's influence on global precedence. Lamb and colleagues make their claim from the differences in RTs between the alternating and constant condition. However, Lamb et al. (1998)'s result section did not show an interaction between the focused level (global, local) and the block types (random, constant, alternating). This indicates that level focus is not responsible for the performance differences between the constant and alternating conditions. Presetting to a level may have been difficult regardless of level focus. Therefore, this design does not effectively portray selective attention's influence on global precedence. From this, it would be reasonable to conclude that Lamb et al. (1998)'s design may have only examined selective attention's ability to adjust the attentional window between the current level and the previously exposed level.

Additionally, closer examination is warranted of the factors involved with the level-repetition effect and selective attention's influence on visual perception for hierarchical letters. Lamb et al. (1998)'s claim requires the assumption that selective attention causes level-repetition only from presetting the attentional window. However, selective attention also reduces the influence of irrelevant information.

Lamb and colleague's method may fail to address this function of selective attention. The alternating condition requires multiple attentional presetting throughout the condition while the constant condition enables strengthened attentional focus at one level throughout the condition. Switching between tasks can reduce performance. This decrease in performance due to task switching is known as switching costs (Dreisbach & Haider, 2008; Monsell, 2003). The alternating condition is similar to task switching; participants must shift their attention and reorient themselves to a different feature. Hence, the constant condition allows for attention to become better set to a level while the alternating condition requires selective attention to rapidly and continuously change focus - never becoming set to one level (Monsell, 2003). It could be that repeating a level strengthens selective attention, increasing the ability to reduce the influence of irrelevant information (Reisenauer & Dreisbach, 2014).[5] In other words, the constant condition strengthens selective attention while the alternating condition does not (Dreisbach, 2012); Strengthening selective attention is necessary to maintain focus on the task-relevant level and inhibit the processing of irrelevant information (Dreisbach & Haider, 2009). Task shielding literature provides further evidence for this idea.

[5] Moreover, continually shifting the attentional window may be fatiguing and dampen selective attention's effectiveness.

TASK SHIELDING

Task shielding is an effect that can be defined as enhanced attention to relevant information or reduction of influence from irrelevant information (Dreisbach, 2012). This effect is thought to occur through participants using cognitive mechanisms to better filter relevancy. Numerous studies look at developing task shielding or the ability to separate different tasks or features (e.g., Dreisbach & Haider, 2008; Reisenauer & Dreisbach, 2014). A fundamental principle of task shielding methods is the implementation of task sets. Tasks sets or rules are defined as cognitively represented rules used to distinguish relevance in a given stimulus (Dreisbach & Haider, 2008). Selective attention uses these rules to maintain focus on relevant information or inhibit the processing of irrelevant information.

Task shielding research focuses on comparing selective attention's ability to reduce influence from irrelevant information between task switching and task repetition; this is done by looking at different tasks for one stimulus type (e.g., Dreisbach & Haider, 2008; Reisenauer & Dreisbach, 2014). Specifically, task shielding research uses Stroop-like interference to assess how shielding affects selective attention.

Stroop-like Interference and Task Shielding

Stroop-like interference is an asymmetrical interference that occurs from encoding and responding to two separate features of an item (e.g., the meaning of a word interferes with the encoding of the color of the word; Stroop, 1935). Saliency is an important aspect of Stroop-like interference; encoding order is dependent on each item feature's saliency (i.e., ability to attract attention) and occurs using non-cognitive mechanisms. Stroop-like interference arises when participants are tasked with identifying one feature in a stimulus. For example, if the word “black” is written in the color “blue”, the meaning of the word “black” interferes when the task is to attend to the color of the word “blue”. However, the color of the word has little effect when the task is to attend to the meaning of the word. In short, the main characteristic of Stroop-like interference is that a salient feature - the meaning of a word - interferes with the processing of, and response to a different, less salient, feature - color of the word. This characteristic is also fundamental for global interference such that the global level interferes with the processing of the local level.

Task shielding methods are known to reduce Stroop-like interference by strengthening selective attention (i.e., increase selective attention’s ability to focus and filter relevancy). In other words, task shielding allows for participants to become more familiar with or better utilize task rules and effectively filter relevant information. These methods often involve tasks where selective attention is used to focus on a task or inhibit the responses to irrelevant tasks or information. For example, tasks may have participants attend either to the color or meaning of the word. Afterwards, participants view a series of different words in different colors and must respond according to the given task. This method forces participants to stay attentive to the task and also reduces the influence of the irrelevant task or information (Dreisbach & Haider, 2009). Dreisbach & Haider (2008) proposes that increase in task-rule activation is the cause for task shielding. Selective attention activates these rules to distinguish relevance. With enough exposures or practice, selective attention becomes stronger which strengthens the activation of these task-rules. This increases attention to relevant information and shielding against irrelevant information when directed to a task, especially when the same task is repeated (Dreisbach, 2012;

Dreisbach & Haider, 2008, 2009; Dreisbach & Wenke, 2011). In short, RTs improve when tasks are repeated because repetition strengthens selective attention's focus to these tasks.

By examining Stroop-like interference with task shielding, studies found that selective attention can be fluid in its strength and efficiency. Specifically, task shielding literature presents evidence that task repetitions can strengthen selective attention and reduce the influence of irrelevant information. Importantly, Stroop-like interference is an asymmetrical interference that closely resembles global interference. Both types of interference rely on saliency and attentional capture. Therefore, it may be worth investigating whether task shielding is also possible for hierarchical stimuli (i.e., global precedence) and responsible for the level-repetition effect.

Lamb et al. (1998) and Task Shielding

Lamb et al. (1998)'s design is similar to task shielding methods. The alternating and constant conditions are parallel to the task switching and task repetition conditions respectively. The alternating and task switching conditions require the ability to switch focus to different information while the constant and task repetition conditions require the ability to maintain focus on repeated information. Lamb and colleagues present rules in their design by having participants focus on particular levels. This is similar to the rules in task shielding studies (Dreisbach & Haider, 2008; Reisenauer & Dreisbach, 2014). Therefore, selective attention is likely to be involved in both the alternating and constant conditions. The mechanism-activation hypothesis is also similar to the task-rule activation hypothesis. Both hypotheses claim that tasks or stimuli activate some mechanism; this mechanism strengthens when repeated. Lamb et al. (1998) interprets their results based on the mechanism-activation hypothesis but their design is also similar to task shielding methods.

In summary, Lamb et al. (1988) posits that non-cognitive mechanisms are responsible for level-repetition effect. However, an alternative explanation for Lamb et al. (1998)'s results could be that cognitive mechanisms are producing and increasing task shielding. Faster responses in the constant conditions may be due to stronger selective attention producing task shielding. The stronger selective attention increases focus to the constantly repeated level by providing additional attention allocation to that level or better inhibition of processing irrelevant information. This increases the encoding speeds for relevant information or reduces the amount of attention captured by irrelevant information. In doing so, relevant information is encoded earlier or interference is lessened from slowing down the processing of the irrelevant information. In short, consecutive task repetitions strengthen selective attention which increases focus to relevant information; this decreases interference from irrelevant information.

Stroop-like interference vs. Global interference

The limits and functionality of selective attention have been tested with a variety of different effects including Stroop-like interference (e.g., Dreisbach & Haider, 2008, 2009; Dreisbach & Wenke, 2011; Reisenauer & Dreisbach, 2014) and global precedence (e.g., Hoffman, 1980; Paquet & Merikle, 1988).

Stroop-like interference occurs from saliency differences between features (meaning vs. color) that are within the same item but between different processing categories (semantic meaning vs. visual perception). Strengthening selective attention with task shielding can reduce Stroop-like interference (Reisnauer & Dreisbach, 2014). But this reduction only applies to weakening the influence of irrelevant information when two item features are from significantly different categories. Unlike Stroop-like interference, global interference occurs from saliency differences between features (large vs. small) that reside within the same item, feature category (size) and processing category (visual perception). In other words, global interference occurs from feature comparisons that are within a niche category unlike Stroop-like interference.

Differentiating nuances between two categories is easier than within one category (Jonides & Gleitman, 1972). The difference in feature comparisons between Stroop-like interference and global interference could influence task shielding’s effectiveness (Reisenauer & Dreisbach, 2014). Compared to Stroop-like interference, global interference requires a more difficult or careful filtration of irrelevant information (i.e., a more selective focus). Therefore, it is currently unknown whether task shielding methods affect global precedence and are responsible for the level-repetition effect seen in Lamb et al. (1998).

OVERVIEW

Lamb et al. (1998) show that presetting attention does not alter the order of encoding set by saliency in hierarchical letter processing; Lamb and colleagues interpret their results as support for the mechanism-activation hypothesis and conclude that non-cognitive mechanisms are responsible for the level-repetition effect on global precedence. However, it is unclear if Lamb et al. (1998)'s methods fully examine selective attention. This is because the methods in Lamb et al. (1998)'s studies do not measure selective attention's ability to inhibit the processing of irrelevant information (i.e., the interference effects between the two levels throughout the block or run). Because Lamb et al. (1998)'s methods are similar to task shielding methods, this inability to measure selective attention's inhibitory features limits Lamb et al. (1998)'s claims.

Our paradigm assigns tasks on situations and stimuli that exhibit global precedence. The stimuli and tasks in our paradigm differ based on focus level and relevant information. This requires participants to be task-driven and use selective attention to distinguish relevancy. These methods allow us to observe selective attention's ability to inhibit the processing of irrelevant information within a specific category. Because strengthening selective attention enhances the ability to mitigate-saliency's influence, participants should become better at maintaining attention to the target level or inhibiting processing of the irrelevant level with each consecutively repeated exposure. This would provide evidence that selective attention's ability to suppress or focus on information is possible between features within niche categories and somewhat responsible for the level-repetition effect.

Following our experiments, we fit our data to models and perform model fit comparisons similar to those used in Logan (1988). This is done to further explore our data and apply Logan's instance theory of automatization to our data. Specifically, we perform these model fits and comparisons to examine if participants are learning from previous exposures.

Experiment 1

Task shielding may be key to understanding selective attention's relationship with global precedence. Our studies use a design similar to Lamb et al. (1998)'s constant condition in their second experiment but we manipulate congruency and look at how interference from incongruent information changes over multiple consecutive repeated tasks. In doing so, we reexamine Lamb et al. (1998)'s claim and look at whether task shielding is possible for hierarchical letters and an alternative explanation for Lamb et al. (1998)'s results.

Our tasks used stimuli with the target consistently present at the relevant level while the irrelevant level changed between congruent and incongruent information at specific trials. Reduction in interference from incongruent information would indicate that selective attention is being enhanced. This would show that Lamb et al. (1998)'s constant condition used some form of selective attention. More importantly, if global precedence is affected by selective attention, then strengthening this attention should reduce global interference. Reduction in global interference would provide evidence that selective attention can influence global precedence. Experiment 1 provides preliminary data on these ideas.[6]

[6] A second study (experiment 3) was also conducted. Experiment 1 is an improved design of experiment 3; therefore, experiment 3 is mainly referenced and reported in Appendix A.

Participants

Experiment 1 had a total of 37 participants. Participants were recruited from the University of South Florida SONA pool and ran in IRB-approved protocol. Participants received extra credit for their participation. Seven participants in experiment 1 were removed due to high proportion of errors. Therefore, we analyzed the data of thirty participants.

Stimuli

There was a total of five different letters (A, E, G, K, U) used for the hierarchical letters at both the global and local levels with six different font styles for each letter. Each font style was chosen based on the differentiating quality of the letters compared to the other font styles. The same six font styles were used for all the letters.[7] The stimulus bank consisted of 150 unique hierarchical items (Global letter x local letter x font style). These hierarchical items have similar conditions and properties (e.g., visual angle, number of elements, etc.) as past studies (e.g., Kinchla & Wolfe, 1979; Lamb et al., 1998; Poirel et al., 2008; Ward, 1982) to ensure global advantages with the stimuli (see Figure 1). Each global letter is created from 40 identical local letters. The local letters have a slight variation of vertical visual angles between the letter ranging from .5 to .8 degrees and the global letter have a slight variation of vertical visual angles between the letters ranging from 7 to 9 degrees.

Design and Task

The experiment was organized by runs. Each run was a series of seven trials that participants completed without a break period. The task for each trial was to search a given stimulus and identify if a target letter was present. The critical manipulations involved the trial

[7] Fonts used: Biz UDPmincho medium, Cambria, Lucida Calligraphy, Rockwell, MV Boli, and Courier New.

number within runs. Each trial is identified by their sequential order in a run, otherwise known as ‘position’ (e.g., the first trial is position one, the second trial is position two…the last trial is position seven). Most trials had a congruent stimulus; the focused and irrelevant levels both contained the target letter. But we manipulated congruency for trials at position two and six (see figure 5); these trials contained either congruent or incongruent stimuli. An incongruent stimulus had the target letter in the focused level while the irrelevant level contained a non-target letter. None of the stimuli were presented twice in a run before the critical position

In the beginning of each run, participants were directed to a level (global or local) and given a target letter (A, E, G, K, U). Then participants were presented with a hierarchical letter and required to respond accordingly (i.e., “yes” or “no”). RT (msec) to correctly respond to the presence of the target was used to measure participants’ performances along with accuracy on detecting the presence or absence of the target. Every participant completed 10 practice runs and 180 experimental runs which were broken down into a total of 1,330 trials. Practice runs were used to get participants familiarized with the stimuli, instructions and procedure as well as exposure to each condition and target letter.

The primary concern for experiment 1 was the amount of interference on trials within globally focused and locally focused runs. This was assessed by the RT difference between the congruent stimulus and the incongruent stimulus at a given position (two or six).

We planned six comparisons to assessed whether multiple repeated exposures would reduce interference from the irrelevant level. Four of our comparisons looked at interference effects at position two and six for globally focused and locally focused runs. The remaining two comparisons looked at the difference in interference effects between position two and six for the two focused level conditions (e.g., the change in interference from position two to position six for locally focused conditions). If Lamb and colleagues are correct, there should be little to no difference in interference between positions two and six for either focused level conditions. However, if selective attention is a factor, then multiple repeated exposures should increase task shielding and reduce interference for both focused level conditions. In other words, the difference in RTs between congruent and incongruent stimulus at position six should be smaller than this difference at position two.

Experiment 1 was a 2 (Focused level; global or local) x 3 (Run type; all congruent, incongruent at two or incongruent at six) within subject designs. There were six different type of runs (Focused level; 2 x Run type; 3). Each participant saw every type of run twenty times. Additionally, there were filler runs to create noise or uncertainty of target presence in the task.[8]

Procedure

Participants sat in front of a 24 in. LCD Macintosh computer screen and pressed keys ("P" for "yes" and "Q" for "no") on a keyboard throughout each study. Participants could adjust the height of the chair but the distance between the chair and the monitor remained fixed. Researchers instructed participants to seat themselves comfortably with their back to the chair and remain in that position throughout the experiment. Participants could move the mouse and keyboard to desired positions. Participants pressed the [spacebar] key to progress through instructional and break periods. The experiment provided two instruction pages before the start of the practice sessions. These instruction pages gave a brief description of hierarchical letters, the objective and procedure of a trial (see figure 3). A run began by initially assigning a target letter to locate at a specified level (e.g., large A); participants voluntarily proceeded through

[8] There were sixty filler run (33% of total experimental runs) which randomized and presented the critical position multiple times in the run or not at all.

these pages at their own pace similar to the instruction pages. Afterwards, the run progressed automatically with required responses after each stimulus presentation until the end of the run. Inside every trial, participants were presented a blank screen for 150 msec, followed by a fixation cross for 150 msec, and then another blank screen for 150 msec. Then, a hierarchical letter appeared for 150 msec which was followed by a blank screen until a response was made.[9] After each response, there was a 500 msec wait period before the start of the next trial (see figure 4). If participants did not respond in 2000 msec after the stimulus presentation, a buzzer noise played to indicate a 'timed out' response and the next trial commenced.[10]

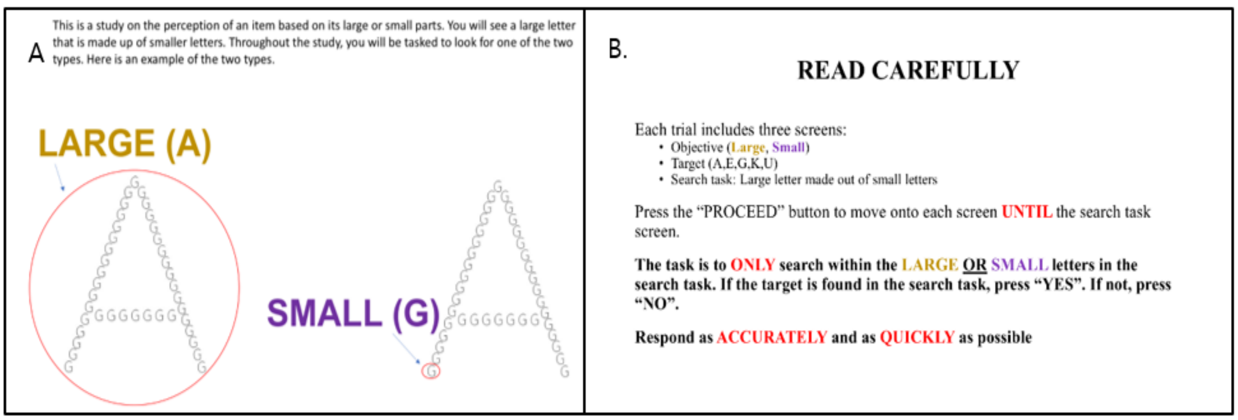

Figure 3. Instruction slides. Description of hierarchical letters (A), description of design and task (B)

[9] Stimulus duration was 200 msec for the first ten trials of the practice block to familiarized participants with brief presentations.

[10] In the practice trials, participants received unique feedback to indicate correct, incorrect and timed-out responses. In the experimental trials, participants did not receive any feedback apart from the timed-out responses.

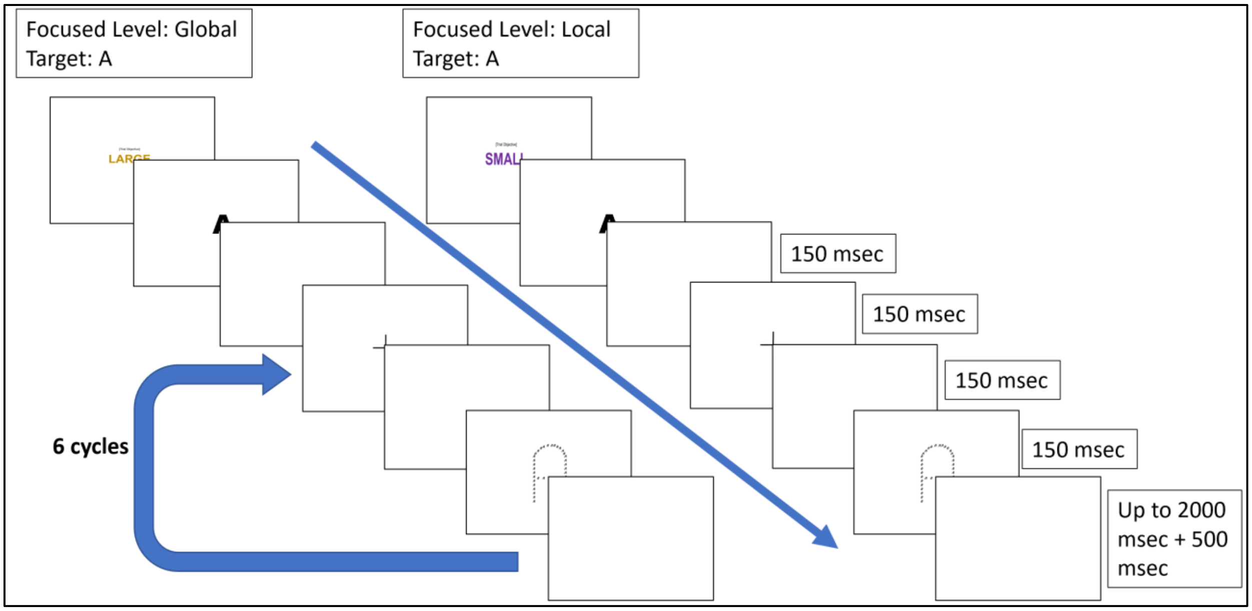

Figure 4. Trial procedure of paradigm. Breakdown of one trial and run.

Results

We used mean RT (msec) as the primary dependent variable for analysis and participants' accuracy as a secondary measure. Before analyzing RTs, we removed incorrect and timed out responses. No outliers were taken out due to the 2000 msec cutoff in the experiment. The resulting RTs were averaged by condition for each participant. There were roughly twenty observations in every condition per participant. The final number of observations per participant were divided by the total number of observations (n = 20) and aggregated to obtain overall accuracy rates (see figure 7). We used dependent sample t-tests to analyze all the planned comparisons. Congruent or baseline runs show a general logarithmic decrease in RTs throughout a run for both globally focused and locally focused conditions. In our graph, black lines represent this condition (see figure 6).

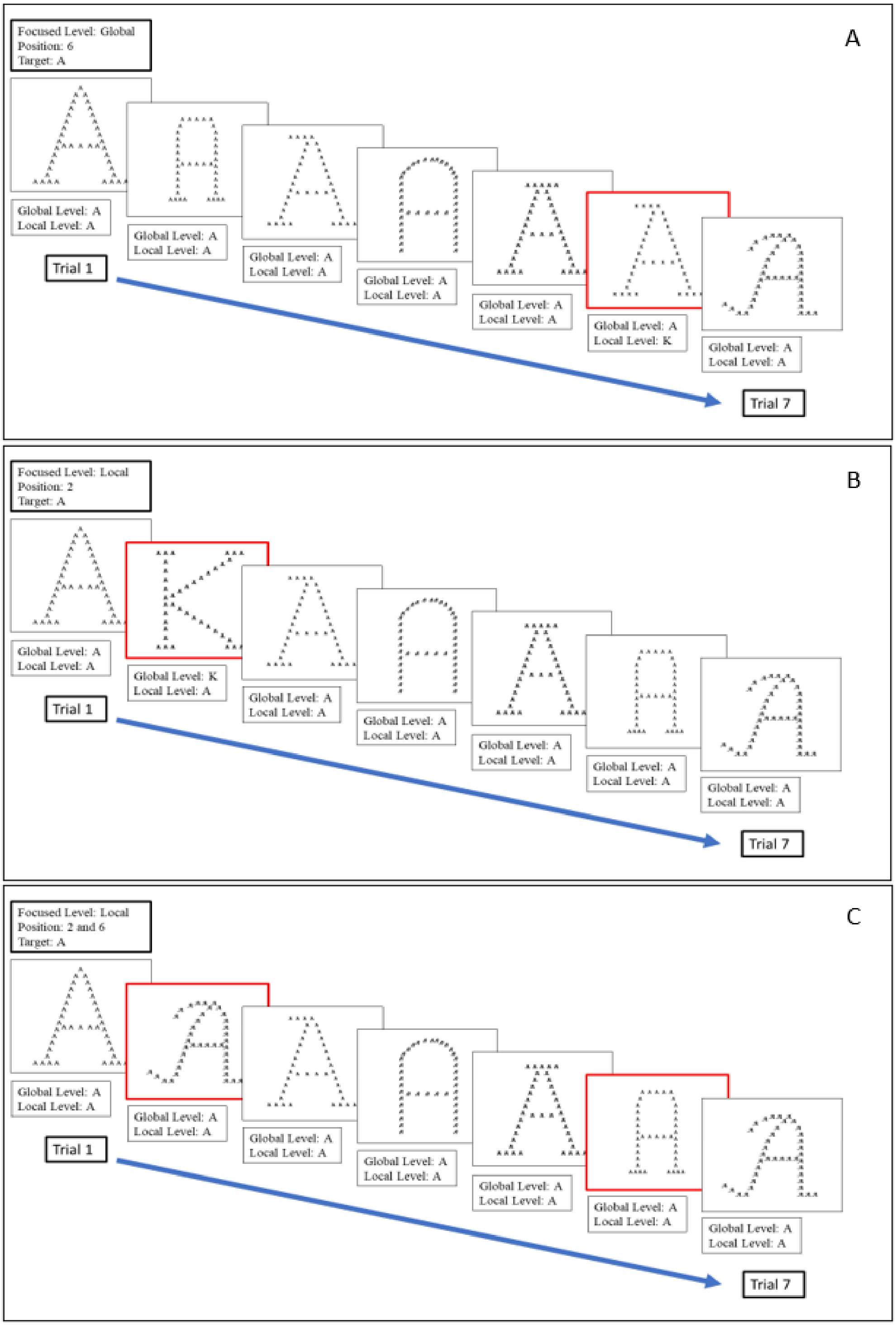

Figure 5. Example of runs within Experiment 1. This shows example sequences of critical stimuli presented in a run. Globally focused run with incongruent stimuli at position six (A); Locally focused run with incongruent stimuli at position two (B); Locally focused run with congruent stimuli throughout the run (C).

Locally Focused Runs. Relative to baseline, position two had significantly elevated RTs (i.e., slower responses) with an incongruent stimulus (Mean difference = 34, SE = 9.34); t(29) = 3.64, *p* = .001, Cohen's *d* = .66. Position six also had significantly elevated RTs with an incongruent stimulus (Mean difference = 25, SE = 8.57); t(29) = 2.86, *p* = .008, Cohen's *d* = .52. There was no significant decrease in interference effects from position two to position six (Mean difference = 9, SE = 9.39); t(29) = 1.00, p = .32, Cohen's *d* = .18.

Globally Focused Runs. Relative to baseline, position two had significantly elevated RTs with an incongruent stimulus. (Mean difference = 28, SE = 7.84); t(29) = 3.59, *p* = .001, Cohen's *d* = .66. Position six did not have a significant elevation in RTs with an incongruent stimulus (Mean difference = -4 SE = 8.00); t(29) = .50, *p* = .62, Cohen's *d* = -.09. Lastly, there was a significant decrease in interference effects from position two to position six (Mean difference = 32, SE = 12.33); t(29) = 2.61, p = .01, Cohen's *d* = .48.

Trimmed Data. To ensure that our results were not compromised by left-skewed RTs, we trimmed RTs below 50 msec – under 4% of correct responses - and reanalyzed our data.[11] Only the reduction of interference effects from position two to position six changed between the two data sets. This reduction did not reliably decrease but became unreliable with the trimmed data. However, we speculate that this loss of reliability arises from the study becoming underpowered from trimming the data. Future studies will address this potential issue.

Discussion

For both globally focused and locally focused runs, results show that presenting an incongruent stimulus at position two increased RTs (i.e., local and global interference, respectively). By position six, this interference effect only occurred for locally focused runs. For

[11] Trimmed data for experiment 1, 2 and model fit comparisons are listed in Appendix B

globally focused runs, one interpretation is that the local level managed to capture some attention at position two because participants are still new to the task (i.e., level focus and target), leading to some local interference. By position six, participants became better at focusing on the global level and inhibiting local level processing (i.e., strengthened selective attention; Dreisbach & Haider, 2008) thereby reducing local interference. Contrastingly, for locally focused runs, task repetition was unable to reduce global interference or the amount of attention captured by the global level. Therefore, one conclusion is that tasking participants to attend to one level and consecutively presenting congruent stimuli in a run can reduce interference when searching the global level but not when searching the local level. This supports Lamb et al. (1998)'s claims; cognitive mechanisms (e.g., selective attention) are unable to reduce global precedence.

However, there are some issues that may prevent task shielding from efficiently improving selective attention, especially for locally focused runs. The key issue is the study design. The runs in the design present a consecutive series of congruent stimuli until the critical position, which presents an incongruent stimulus. Participants continually search for the same target letter in a single run. Therefore, participants are seeing the same general shape throughout a run until the critical position in the observed conditions. The critical position shows an incongruent stimulus which is different from the previous stimuli in terms of shape. Because the global level has stronger saliency, changes in the global shape would have a stronger visual impact than changes in the local shape; this could limit task shielding's ability to strengthen selective attention for the locally focused conditions. After repeated exposures of similar shaped congruent stimuli, the sudden presentation of a differently shaped stimuli can produce an abrupt change. This can be problematic as abrupt changes can disrupt focus and capture attention (Krumhansel, 1982). The abrupt change in global structure could focus attention to the changed feature while also jarring participants. Originally, our study used different font styles to address this issue. We provided various font styles for each letter and stimulus presentation to increase variation in stimulus shape and prevent participants from perceiving the same object for each congruent stimulus throughout a run, However, simply changing font styles may not add enough variation to accomplish this goal. This may be a potential explanation to the continued interference effect for the locally focused conditions. Locally focused runs had reduced shielding effects because selective attention had to refocus attention to the target level when participants were presented with an incongruent stimulus.

Another potential problem with this design is the constant presence of congruent information at the irrelevant level. An alternative explanation for our results may be that presenting a congruent stimulus (i.e., target at the irrelevant level) prevents participants from focusing on task rules and reduces the need to develop shielding of the irrelevant level for subsequent positions. Specifically, when presented with a congruent stimulus, participants may fail to inhibit the processing of the irrelevant level. This is because congruent stimuli facilitate performance (Hoffman, 1980). Furthermore, inhibition requires spending limited attentional resources (Engle et al., 1995); therefore, participants may not allocate limited resources to inhibit information processing that facilitates performance. This congruence effect may adversely affect locally focused runs more than globally focused runs. For globally focused runs, participants attend to both the global and local levels at the start of a run, but eventually adhere to task rules because local level processing is unnecessary due to baseline (i.e., global to local) order of hierarchical letter processing. For locally focused runs, participants start a run similar to globally focused runs but do not adhere to task rules and fail to inhibit global level processing because the global level facilitates local level processing. Accordingly, participants attend to the global level and never learn to ignore this level; when presented with an incongruent stimulus, participants are unable to inhibit global level processing because efficient task shielding did not develop. The purpose of the consecutive repeated task exposure is providing additional time to set selective attention and develop shielding of the irrelevant level. By providing a congruent stimulus, participants may not develop efficient task shielding of the irrelevant global level for locally focused runs. Therefore, this design may not allow participants to properly utilize the repeated task exposures. The following study will address this potential issue.

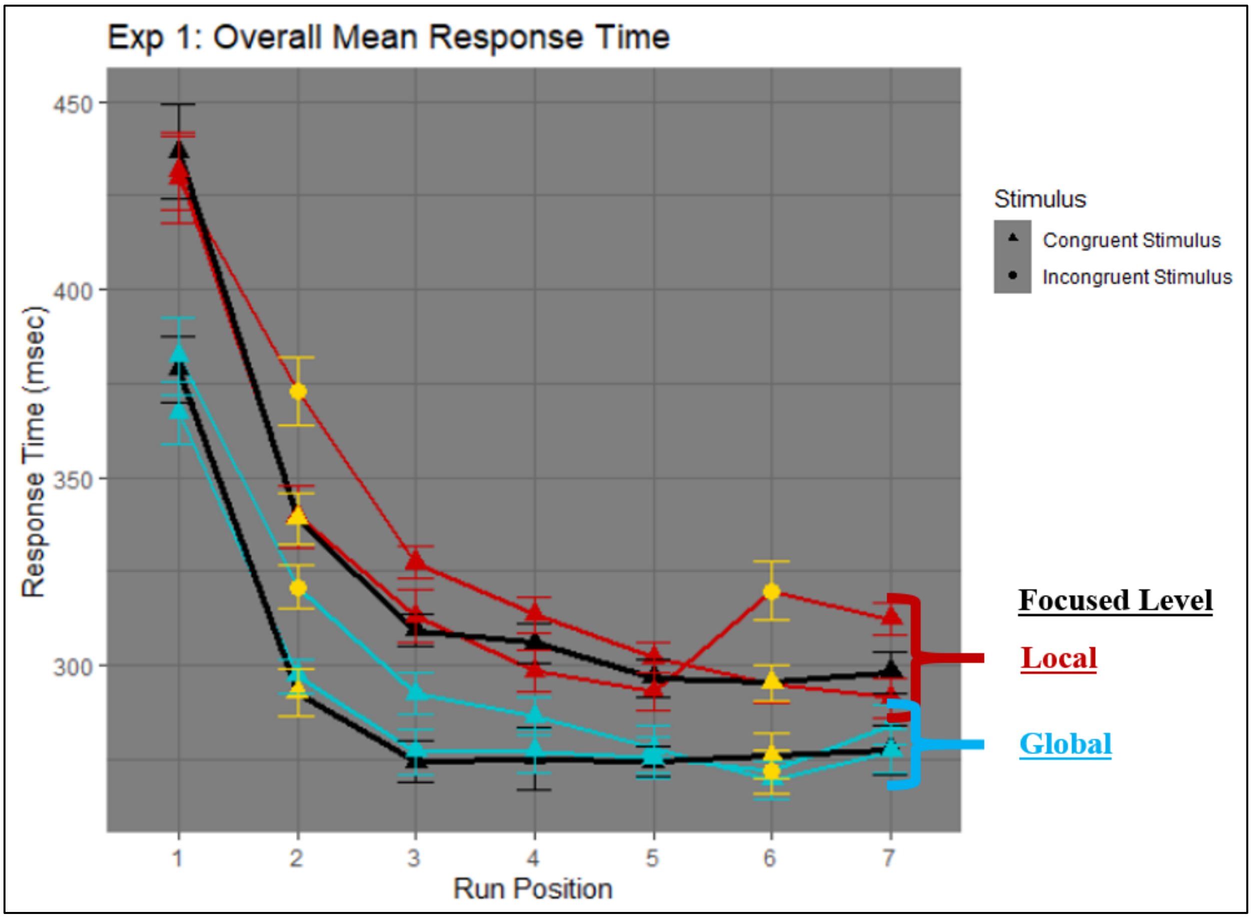

Figure 6. RT results from Experiment 1. Highlighted data points represent concerned or examined observations; black lines represent congruent runs; error bars represent within subject standard errors.5

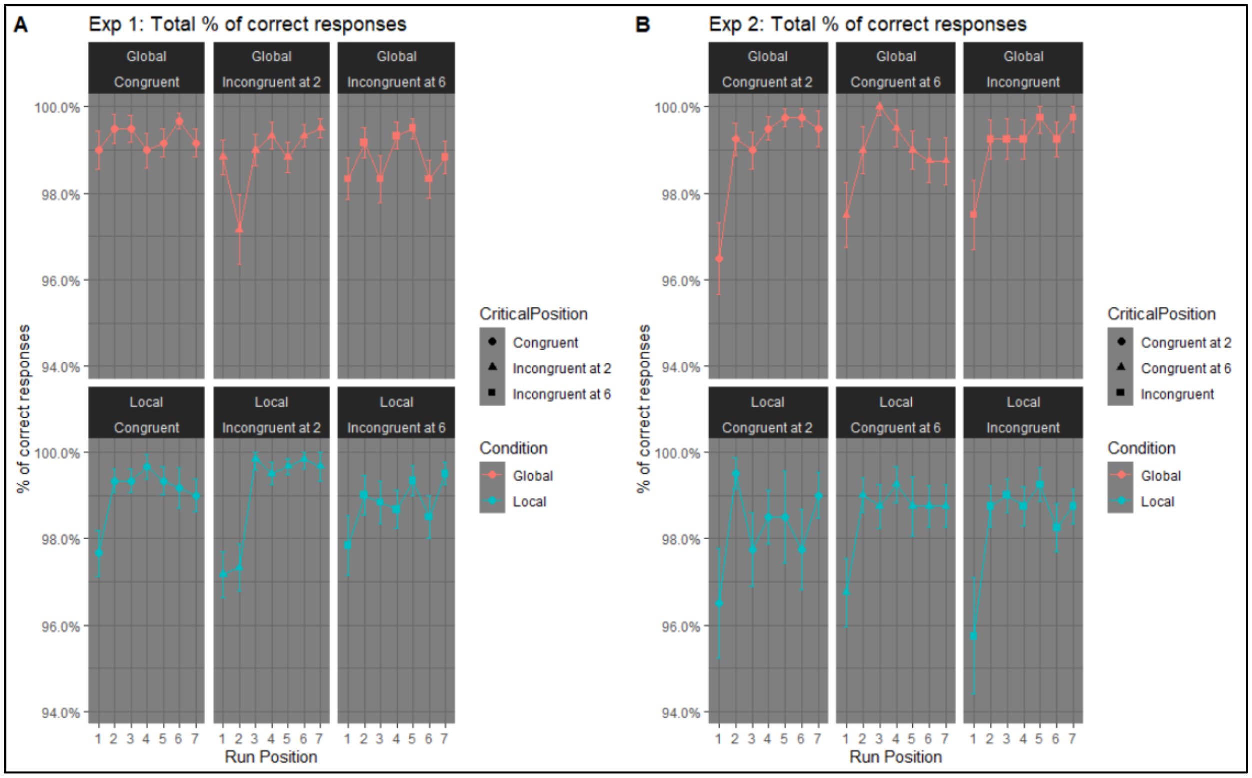

Figure 7. Accuracy rate results. (A) Average percentage of accuracy rates per participant after removing incorrect or timed out responses in experiment 1. (B) Average percentage of accuracy rates per participant after removing incorrect or timed out responses in experiment 2.

Experiment 2

This experiment reverses the design of experiment 1 by altering the runs while using the same stimuli, task and procedure. This design repeatedly presents incongruent stimuli in a run with a congruent stimulus at the critical positions (see figure 9) instead of repeatedly presenting congruent stimuli and then an incongruent stimulus at the critical positions (see figure 5). This change in the design addresses the potential issues in experiment 1. The locally focused or globally focused runs show a variety of different global or local shapes respectively and enables participants to become accustomed to sudden shape changes. Additionally, participants learn to ignore the irrelevant level, strengthening selective attention's focus on the relevant level or inhibition of the irrelevant level. Lastly, this design looks at dampened facilitating effects rather than interference effects. If the influence of irrelevant level decreases, then both facilitating and interfering aspects of the irrelevant level should be reduced.

Participants

Experiment 2 had a total of 23 participants. Participants were recruited from the University of South Florida SONA pool and ran in IRB-approved protocol. Participants received extra credit for their participation. Three participants in experiment 2 were removed due to high proportion of errors. Therefore, we analyzed the data of twenty participants.

Results

For experiment 2, results were analyzed in a similar manner as experiment 1.[12] Incongruent or baseline runs show a general logarithmic decrease in RTs throughout a run for both globally focused and locally focused conditions. In our graph, black lines represent this condition (see figure 8).

Locally Focused Runs. Relative to baseline, position two had significantly lower RTs (i.e., faster responses) with a congruent stimulus (Mean difference = 22, SE = 9.85); t(19) = 2.26, p = .04, Cohen's d = .51. Position six did not have significantly lower RTs with a congruent stimulus (Mean difference = 14, SE = 10.1); t(19) = 1.41, p = .17, Cohen's d = .32. There was no significant decrease in facilitation effects from position two to position six (Mean difference = 8, SE = 10.9); t(19) = .64, p = .47, Cohen's d = .17.

[12] It is worth noting that, for the purposes of this master's defense, this experiment was analyzed with half the desired number of participants (n = 40). Therefore, these analyses are preliminary and underpowered.

Globally Focused Runs. Relative to baseline, RTs were not significantly lower with a congruent stimulus at position two (Mean difference = 10, SE = 8.1); t(19) = 1.19, p = .25, Cohen's d = .27, or position six (Mean difference = 5, SE = 8.1); t(19) = .64, p = .53, Cohen's d = .14. There was also no significant decrease in facilitation effects from position two to position six (Mean difference = 4.5, SE = 10.17); t(19) = .44, p = .66, Cohen's d = .10.

Trimmed Data. Similar to experiment 1, we looked at the differences between trimmed data (under 4% of correct responses) and untrimmed data. No differences were found.

Discussion

Results from experiment 2 differed from experiment 1. For globally focused runs, a congruent stimulus provided no facilitation effects at positions two or six. In other words, RTs did not reliably become faster at either positions with a congruent stimulus. Likewise, there were minimal differences in facilitation effects between the two positions. Unlike experiment 1, results from experiment 2 show that the local level had little influence at either positions two or six. It is likely that the incongruent stimulus at the first position informs participants to ignore the irrelevant (i.e., local) level for subsequent trials within the run. This provides support for our suspicions regarding the influence of congruent stimulus presentation in experiment 1.

The results for locally focused runs are similar to the results for globally focused runs in experiment 1. Therefore, similar interpretations are made for the locally focused runs in experiment 2. The faster RTs at position two for locally focused runs signifies that congruent global levels facilitate performances. The disappearance of this effect at position six suggests weaker global level influences at this stage in a run. However, unlike the results for globally focused runs in experiment 1, the difference (i.e., decrease) in facilitation effects between positions two and six was not reliable. Therefore, we tentatively conclude that task shielding had little effect on reducing the global level's influence. Experiment 2 provides further evidence that are consistent with Lamb et al. (1998)'s conclusions; selective attention has little effect on reducing global precedence.

The differences between the results for experiments 1 and 2 provide support for the potential issues raised for experiment 1. The irrelevant level only contained the target during the manipulated positions (two or six). Therefore, a possible explanation is that participants learned to focus only on the relevant level throughout the runs. In other words, participants were able to more easily apply task rules because participants did not receive facilitation from the irrelevant level in positions preceding the critical position.

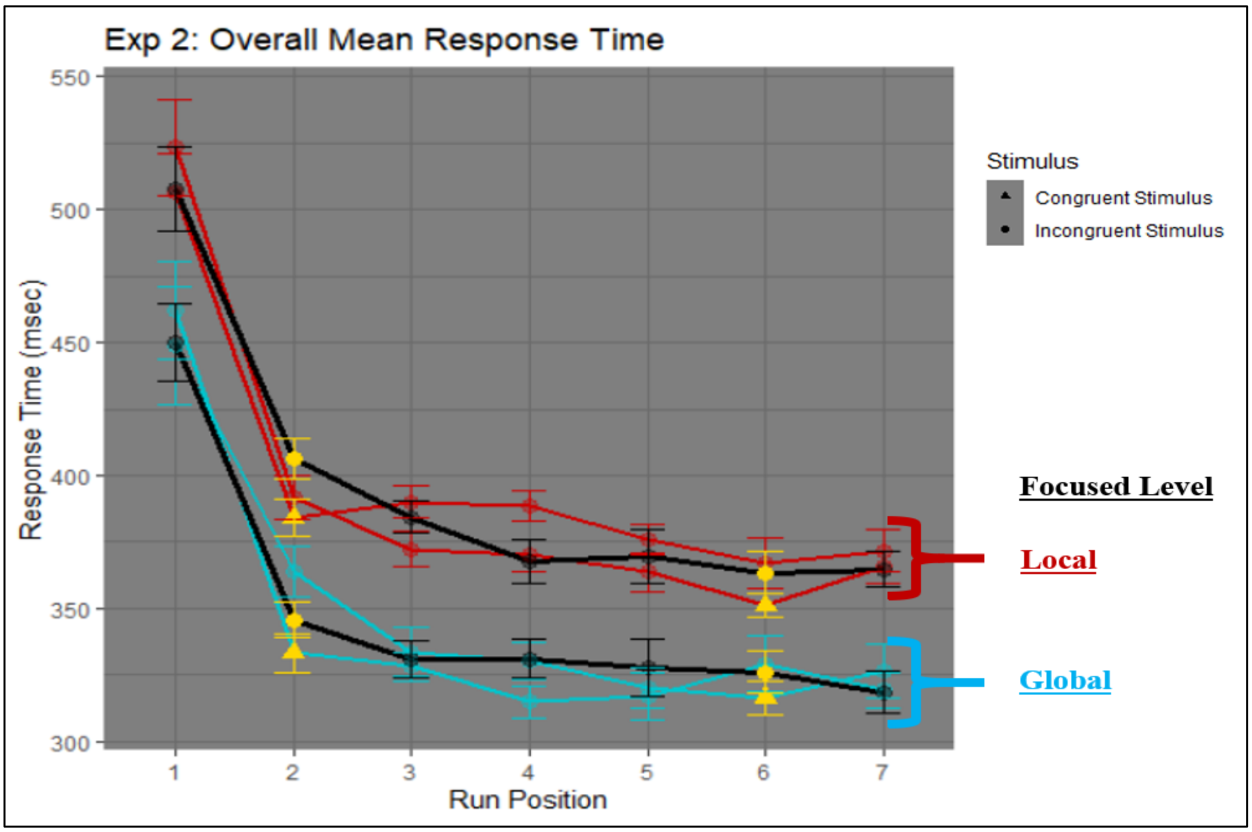

Figure 8. RT results from Experiment 2. Highlighted data points represent concerned or examined observations; black lines represent incongruent runs; error bars represent within subject standard errors.

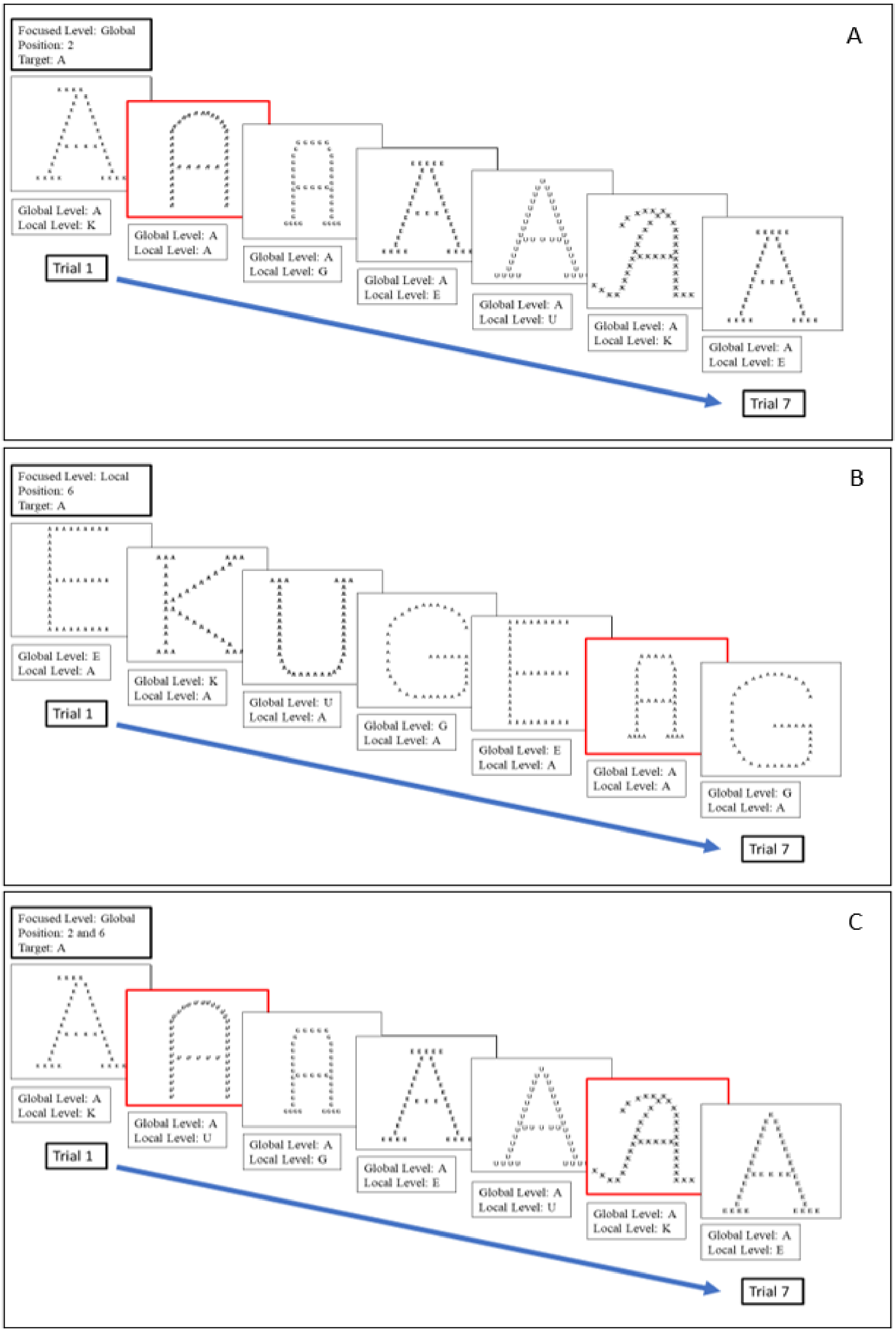

Figure 9. Example of runs within Experiment 2. This shows example sequences of critical stimuli presented in a run. Globally focused run with congruent stimuli at position two (A); Locally focused run with congruent stimuli at position six (B); Globally focused run with incongruent stimuli throughout the run (C).

Instance Theory of Automatization

The basis of our position manipulation (critical stimulus at position two vs. six) relies on the assumption that participants are learning from previous exposures or tasks (i.e., becoming more familiar with task sets or rules) and utilizing these task sets or rules. To evaluate these assumptions in a formal manner, we look to Logan (1988)'s instance theory of automatization. The instance theory of automatization states that people first complete tasks with a general algorithm that is sufficient to perform and finish the task; this is eventually replaced by a more specific set of solutions or strategies that are based on past experiences or memories (Logan, 1988). In other words, people first use a generalizable or generic set of actions and decisions that are flexibly applicable to all tasks, but, with repetition, people eventually learn to utilize more optimal and specific strategies – often from memory retrieval - to complete these tasks.

Logan (1988) explains the instance theory of automatization in terms of a race between instances retrieved from memory and a general algorithm; the process that finishes first completes the task. Initially, the algorithm finishes first but with each task repetition, more instances are encoded and introduced into the race, increasing the likelihood of an instance overtaking and finishing before the algorithm (Logan, 1988). Instances winning this race represent task performance methods "switching" from general algorithms to the strategies based on learned instances retrieved from memory. This theory predicts that both RTs to complete a task and the standard deviations (SD) associated with these RTs follow a power-function speed-up model ($RT = a + bN^{-c}$) and decrease in a similar manner (see Logan, 1988 for more details). "RT" represents the time required to complete a task, "N" is the number of practice trials, and "a", "b" and "c" are constants; "a" represents the asymptote or the limit of learning, "b" is the difference between initial performance and asymptotic performance (i.e., the amount learned) and “c” is the rate of learning. The theory states that a good model fit with an equal rate of learning between mean RTs and mean SDs is an indication that learning or practice effects have occurred and people have switched strategies. Logan simulated and examined participant task performance on lexical decision and alphabet arithmetic tasks to verify this theory and found results confirming his ideas (Logan, 1988).

In order to determine whether participants are learning from past tasks, we fit our data (experiments 1 and 2) to the power-function speed-up model and use Logan (1988)’s instance theory of automatization to interpret the results. To do this, we apply Logan (1988)’s methods; we fit our mean RT and mean SD data to two different versions of the power-function speed-up model and compare the overall (averaged values based on mean RT and mean SD values) and individual (solely mean RT or mean SD values) goodness of fits (r^2 or *rmsd*; root-mean-squared deviation) between these versions (see tables 1 and 2). The first version uses separate rate of learning values for mean RTs and mean SDs while the second version constrains the rate of learning values to be identical; these models will be referred to as the separate fit model and constrained fit model, respectively.

Model Fits

To fit the two versions (separate rate of learning vs. constrained rate of learning) of the power-function speed-up model, we performed a minimization loop to obtain near optimal parameter values for each of our conditions. This was done by repeatedly fitting different values for each parameter until acceptable sums of squared errors (SSE) were found. In our minimization loop, we constrained parameters “a” and “b” to prevent the model from settling at local minimas or global maximas. Parameter “a” values were constrained to be within “70” msec below parameter “b” values. Parameter “b” values were constrained to be greater than zero.

Lastly, we constrained parameter "c" values to be between "0" and "6". In order for the model to produce a decreasing power-function, the exponential value "c" needs to be above "0". We set the upper limit for the rate of learning values to be "6" because values above this number did not further affect the goodness of fit values for our data but increased the chances of the model settling at local minimas and global maximas. This analysis was programmed and examined within Rstudio.

Results

The results show that the constrained fit model produced similar values as the separate fit model within both experiments 1 (see table 1) and 2 (see table 2). Model fit comparisons between the separate and constrained models show that the two models produced similar SSEs for every condition in both experiments 1 and 2 (see table 3); this indicates that the separate model did not outperform the constrained model.

Goodness of Fit. For every condition in experiments 1 and 2, overall r^2 values had little to no differences between the separate and constrained model fits; therefore, only the constrained fit values are reported. For mean RTs, r^2 was above .95 in every condition for both experiment 1 and 2 (see tables 1 and 2). Experiments 1 and 2 both had lower r^2 for mean SDs compared to mean RTs. Experiment 1 also had worse r^2 than experiment 2; r^2 for mean SDs ranged between .2 - .9 for experiment 1 and.6 - .9 for experiment 2

Additionally, overall *rmsd* values were similar between the separate and constrained fits for every condition in experiments 1 and 2; therefore, only the *rmsd* values for the constrained model fit are reported. For mean RTs, *rmsd* values were relatively small (between 4 - 17 msecs for data that ranged between 250 - 550 msec). For mean SDs, *rmsd* values were comparably larger than mean RTs (between 9 - 25 msec for data that ranged between 100 - 180 msec) in both experiments 1 and 2.

Rate of Learning Parameter. For every condition in experiment 1, separate and constrained fits for mean RTs had similar rate of learning values. For experiment 2, the "congruent at two" condition for globally focused runs ("c" difference = 2.524) had the largest difference in rate of learning values between the separate and constrained model fits.

The separate and constrained fits for mean SDs produced relatively different rate of learning values in multiple conditions for both experiments 1 and 2. For experiment 1, the "congruent" ("c" difference = 1.075) condition for locally focused runs had the largest difference in rate of learning values between separate and constrained model fits. For experiment 2, the "incongruent" ("c" difference = 2.943) condition for globally focused runs and the "congruent at two" ("c" difference = 2.096) and "congruent at six" ("c" difference = 2.241) conditions for locally focused runs had relatively large differences. Notably, the "incongruent" condition for globally focused runs and "congruent at two" condition for globally focused and locally focused runs in experiment 2 had reached the ceiling of our parameter constraints. This indicates that the differences between rate of learning values for mean RTs or mean SDs in these conditions are likely to be higher.

Trimmed Data. To ensure that our results were not compromised by left-skewed RTs, we looked at the model fits and the model fit comparisons for the trimmed RTs in experiments 1 and 2. We found no differences between the trimmed and untrimmed data.

Discussion

The model fit comparisons show that the separate and constrained model produced similar SSEs. Normally, this would suggest that mean RTs and mean SDs had similar rates of learning and that participants were switching to instance-based strategies or utilizing information from previous exposures (e.g., Logan, 1988). However, a critical aspect of Logan's instance theory of automatization is the progressive performance of mean RT and mean SD with each instance (i.e., task presentation and completion) and whether they follow the power-function speed-up model. This is assessed with goodness of fits. [13] For both experiments 1 and 2, goodness of fit values (specifically r^2) show that both the separate and constrained models had great fits ($r^2 > .75$) to observed mean RTs (see figures 10 and 12), indicating a power-function speed-up pattern. For mean SDs, the models were able to adequately fit to most of the conditions in experiments 1 and 2 but some conditions showed comparably low model performances (r^2 < .65). These low r^2 values could be an indication that performance does not follow a power-function speed-up pattern and participants did not switch to instance-based strategies in these conditions. An alternative interpretation is that performance does follow a power-function speed-up pattern but our manipulations interfere with this pattern. To better interpret these r^2 values, we look at the visual representation (i.e., the figures) for mean SD and its progression throughout a run within each experiment and condition.

Experiment 1. For mean SDs, separate and constrained models had similar goodness of fits (see table 1). However, nearly every condition (with the exception of the "congruent" condition in locally focused runs; $r^2 = .89$) had relatively low r^2.

For globally focused runs, Figure 11 provides support that observed mean SD runs did not follow power-function speed-up patterns and participants did not switch to instance-based strategies in these conditions. Specifically, Figure 11 shows that observed mean SDs oscillated

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[13] It is worth noting that the relative distinction of good vs. bad or low r^2 was made post hoc and based solely on the researcher's interpretation of good or bad r^2 values.

above and below the model mean SDs and did not reach asymptote performance. These results are agreeable with the global precedence literature; participants did not have to use a new strategy past the general algorithm because the general algorithm already prioritizes the global level.

For locally focused runs, Figure 11 provides support that observed mean SD runs exhibited a power-function speed-up pattern; however, the presentation of an incongruent stimulus (i.e., our manipulations) disrupts these patterns. For the "incongruent at two" condition, mean SD is highest at position two (~165 msec) and asymptote performance is delayed. This is likely due to global interference caused by the incongruent stimulus presented at position two. One indication of this is the large portion of the SSE for mean SD (SSE = 1167 msec) accrued at this position (squared errors = 597 msec). For the "incongruent at six" condition, the observed mean SD runs look similar to a power-function speed-up pattern until position six where mean SD increases (~160 msec). Similar to the "incongruent at two" condition, this increase in mean SD is likely due to global interference caused by the incongruent stimulus presented at position six. Once again, a large portion of the SSE for mean SD (SSE = 1452 msec) is accrued at this position (squared errors = 886 msec). Figure 10 provides additional support by showing an increase in observed mean RT at position six.

The results from the model fit comparisons, interpretations based on Logan's instance theory of automatization, and Figure 11 all provide support for the conclusions in experiment 1. For globally focused runs, participants do not alter from the baseline order of hierarchical letter processing (i.e., general algorithm). For locally focused runs, participants switch to instance-based strategies after multiple task exposures (i.e., by position six) but an incongruent stimulus still affects RTs; this implies that the global level is still processed despite switching strategies and suggests that multiple task exposures – or at least six repeated task exposures – do not enable effective task shielding for locally focused runs.

Interestingly, the "congruent" and "incongruent at six" conditions have a relatively large difference in mean SDs at position two for locally focused runs (see figure 11). Currently, there are no theoretical explanation for this difference since no manipulation occurred by this position in either conditions. However, large SEs suggest that this is due to noisy participant data.

Experiment 2. Separate and constrained models had similar and good fits to mean SDs with the exception of the "congruent at two" (r^2 = .58) condition in locally focused runs. This indicates that participants relied on instances in every globally focused run and most of the locally focused runs. These results are consistent with our conclusions for experiment 2. For globally focused runs, participants learned to ignore the irrelevant level based on the first position. For locally focused runs, participants only learned to ignore the irrelevant level after multiple repeated exposure (i.e., position six). However, Figure 13 presents inconsistent information to some of the conclusions made for experiment 2 and the results from the model fit and model fit comparisons for experiment 2.

In globally focused runs, Figure 13 presents inconsistent information for the "congruent at two" and "congruent at six" conditions. For the "congruent at two" condition, Figure 13 shows that observed mean SD decreased considerably at position two – likely due to the level-repetition effect - but continually increased afterwards with each subsequent position until position seven. Although r^2 is good for this condition (r^2 = .78), the continually increasing observed mean SDs shows that performance did not follow a power-function speed-up pattern. For the "congruent at six" condition, Figure 13 shows that the observed mean SD run followed a power-function speed-up pattern until position seven where observed mean SD increased. One interpretation for the increase in mean SDs in these two conditions is that the congruent stimulus attracts participants' attention to the irrelevant local level and causes attentional focus to the incongruent local level for subsequent positions. This would indicate that participants did not learn to ignore the local level, even when they switched to instance-based strategies.

In locally focused runs, Figure 13 supports the conclusions for the "congruent at two" condition but provides inconsistent information for the "congruent at six" condition. For the "congruent at two" condition, Figure 13 shows that the observed mean SD run pattern is similar to the one shown in Figure 11 (i.e., experiment 1) for the "incongruent at two" condition in globally focused runs; observed mean SDs oscillated above and below the model mean SDs and do not show an asymptote performance. Therefore, the low r^2 for mean SDs and Figure 13 indicate that participants did not switch to instance-based strategies in this condition; this provides support that participants were unable to ignore the global level, causing a congruent global level at position two to facilitate performance. For the "congruent at six" condition, Figure 13 shows that observed mean SDs reached asymptote performance by position six but mean SD increased at position seven. The large increase in observed mean SDs in Figure 13 provides further support that the congruent stimulus at position six drew attention to the irrelevant level and reduced performance at position seven when the global level became incongruent. Interestingly, this pattern is similar to the increase in mean SD at position three for the "congruent at two" condition; this suggests that a similar effect occurred in the "congruent at two" condition.

For some conditions, one explanation for the inconsistent interpretations from the visual representations may be linked to the rate of learning values. High rate of learning values indicate instant asymptote performance. However, these values can produce inaccurate models by fitting to the data averages. For example, if performance oscillates between high and low RTs or SDs, the model may indicate an asymptote performance between these values to minimize SSE despite observed mean RTs or SDs not reaching asymptote performance. This is likely the case for the "congruent at two" conditions for both globally and locally focused runs in experiment 2. It is also likely that these oscillating behaviors and inconsistent model fits may be due to the underpowered nature of experiment 2. Therefore, we cautiously make these conclusions.

Table 1. Model fit data table for Experiments 1. The table presents parameters a, b, and c and goodness of fit (r^2, *rmsd*) values for mean RT and mean SD. The table also presents overall (average values between mean RT and SD) goodness of fit values.

Table 1

Model Fit Data Table

Experiment 1 – Constrained fit

	Mean RT data					Mean SD data					Overall data	
Condition	a	b	c	r^2	*rmsd*	a	b	c	r^2	*rmsd*	r^2	*rmsd*
Global Congruent	274	105	2.703	0.995	4.370	121	21		0.465	13.376	0.705	8.873
Global Incongruent at 2	251	131	0.971	0.991	5.988	117	25		0.307	18.053	0.600	12.021
Global Incongruent at 6	274	93	2.274	0.981	7.538	125	8		0.195	9.607	0.513	8.573
Local Congruent	292	146	1.793	0.996	4.982	113	58		0.886	11.615	0.941	8.299
Local Incongruent at 2	216	216	0.554	0.990	8.265	84	79		0.629	22.651	0.799	15.458
Local Incongruent at 6	301	131	1.928	0.952	16.562	130	44		0.489	25.474	0.702	21.018

Experiment 1 – Separated fit

	Mean RT data					Mean SD data					Overall data	
Condition	a	b	c	r^2	*rmsd*	a	b	c	r^2	*rmsd*	r^2	*rmsd*
Global Congruent	274	105	2.688	0.995	4.369	121	21	2.928	0.465	13.371	0.705	8.870
Global Incongruent at 2	253	129	1.013	0.991	5.952	102	39	0.417	0.320	17.880	0.609	11.916
Global Incongruent at 6	274	93	2.279	0.981	7.538	125	8	2.030	0.196	9.603	0.513	8.571
Local Congruent	289	149	1.634	0.997	4.417	117	56	2.868	0.908	10.434	0.952	7.426
Local Incongruent at 2	198	233	0.490	0.990	8.105	46	116	0.310	0.638	22.373	0.804	15.239
Local Incongruent at 6	303	130	2.091	0.953	16.446	121	51	1.069	0.510	24.946	0.714	20.696

Table 2. Model fit data table for Experiments 2. The table presents parameters a, b, and c and goodness of fit (r^2, *rmsd*) values for mean RT and mean SD. The table also presents overall (average values between mean RT and SD) goodness of fit values.

Table 2

Model Fit Data Table

Experiment 2 – Constrained fit

	Mean RT data					Mean SD data					Overall data	
Condition	a	b	c	r^2	*rmsd*	a	b	c	r^2	*rmsd*	r^2	*rmsd*
Global Incongruent	326	125	3.057	0.992	6.441	123	60		0.869	13.660	0.930	10.051
Global Congruent at 2	323	139	5.948	0.986	10.195	125	70		0.778	22.673	0.879	16.434
Global Congruent at 6	314	136	1.608	0.990	7.515	125	54		0.765	16.540	0.874	12.028
Local Incongruent	356	152	1.596	0.998	4.041	128	53		0.880	10.738	0.938	7.390
Local Congruent at 2	378	129	3.904	0.974	12.687	139	27		0.580	13.759	0.764	13.223
Local Congruent at 6	361	163	2.538	0.992	8.604	124	75		0.937	11.343	0.964	9.974

Experiment 2 – Separated fit

	Mean RT data					Mean SD data					Overall data	
Condition	a	b	c	r^2	*rmsd*	a	b	c	r^2	*rmsd*	r^2	*rmsd*
Global Incongruent	323	127	2.423	0.996	4.808	125	59	6.000	0.904	11.717	0.949	8.263
Global Congruent at 2	321	142	3.424	0.991	8.165	125	70	6.000	0.778	22.661	0.881	15.413
Global Congruent at 6	311	138	1.494	0.990	7.330	129	52	2.316	0.777	16.115	0.881	11.723
Local Incongruent	356	151	1.611	0.998	4.035	127	54	1.493	0.880	10.720	0.938	7.378
Local Congruent at 2	376	130	3.334	0.974	12.547	139	27	6.000	0.606	13.330	0.779	12.939
Local Congruent at 6	358	165	2.256	0.993	8.029	127	73	4.779	0.955	9.567	0.974	8.798

Table 3. Model fit comparisons for Experiments 1 and 2. The table presents the model fit comparisons for experiments 1 and 2 between the separate (SSE – Full) and constrained (SSE – Reduced) models.

Table 3

Model Fit Comparison

Experiment 1

	SSE - Reduced	SSE - Full	MSE	F	*p*
Global Incongruent	462.053	461.73	57.716	0.006	**0.942**
Global Congruent at 2	844.12	828.594	103.574	0.15	**0.709**
Global Congruent at 6	347.925	347.771	43.471	0.004	**0.954**
Local Incongruent	372.715	299.569	37.446	1.953	**0.200**
Local Congruent at 2	1356.559	1321.255	165.157	0.214	**0.656**
Local Congruent at 6	2154.185	2083.132	260.392	0.273	**0.616**

Experiment 2

Experiment 2	SSE - Reduced	SSE - Full	MSE	F	*p*
Global Incongruent	532.199	374.265	46.783	3.376	**0.103**
Global Congruent at 2	1442.002	1353.759	169.220	0.521	**0.491**
Global Congruent at 6	770.097	731.322	91.415	0.424	**0.533**
Local Incongruent	307.148	306.119	38.265	0.027	**0.874**
Local Congruent at 2	817.347	781.917	97.740	0.363	**0.564**
Local Congruent at 6	472.976	363.963	45.495	2.396	**0.160**

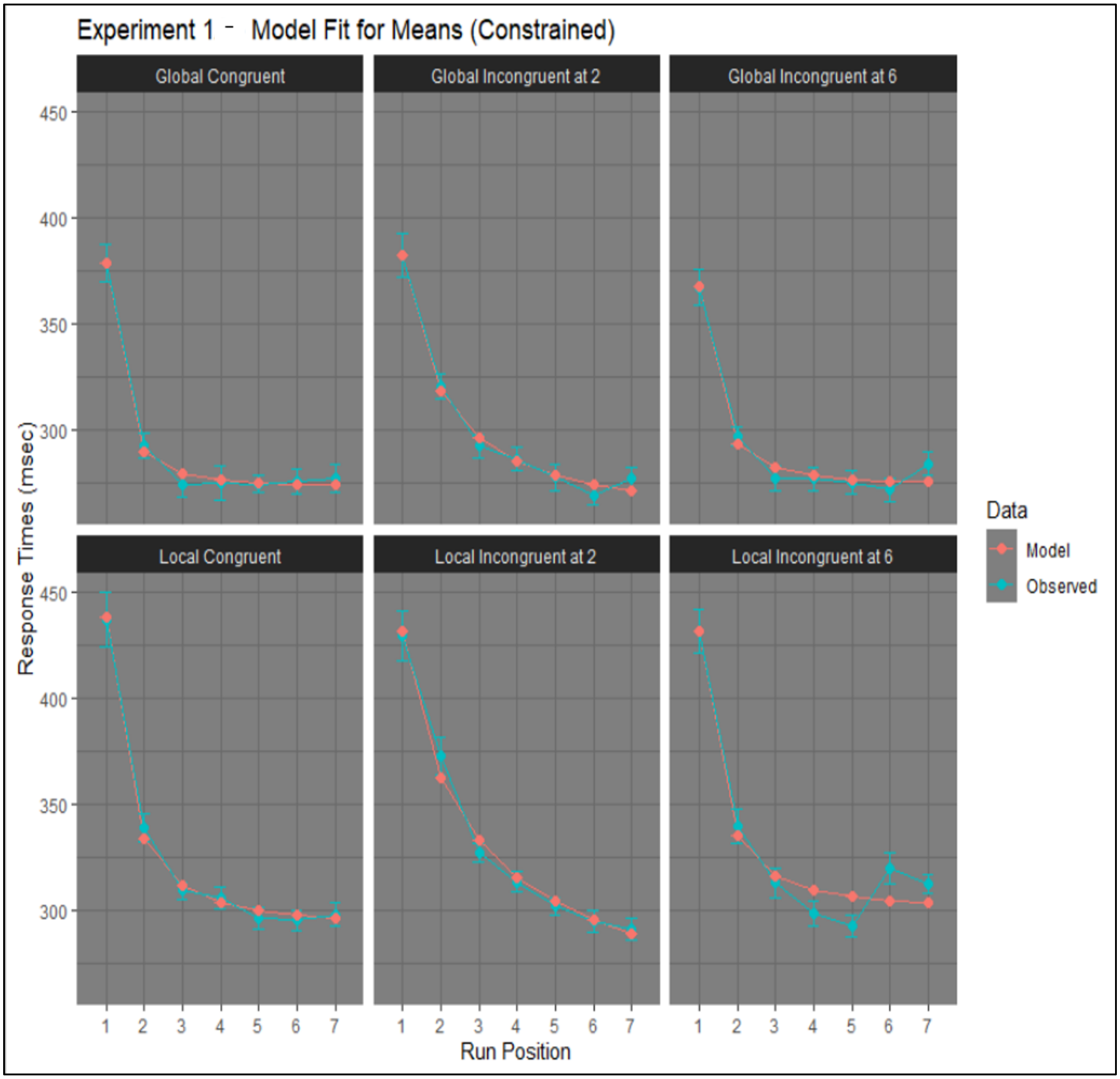

Figure 10. Model fits for mean RTs in Experiment 1. Predicted constrained and separate model values for mean RTs compared with participant data from experiment 1. Each prediction and participant data are separated by condition.

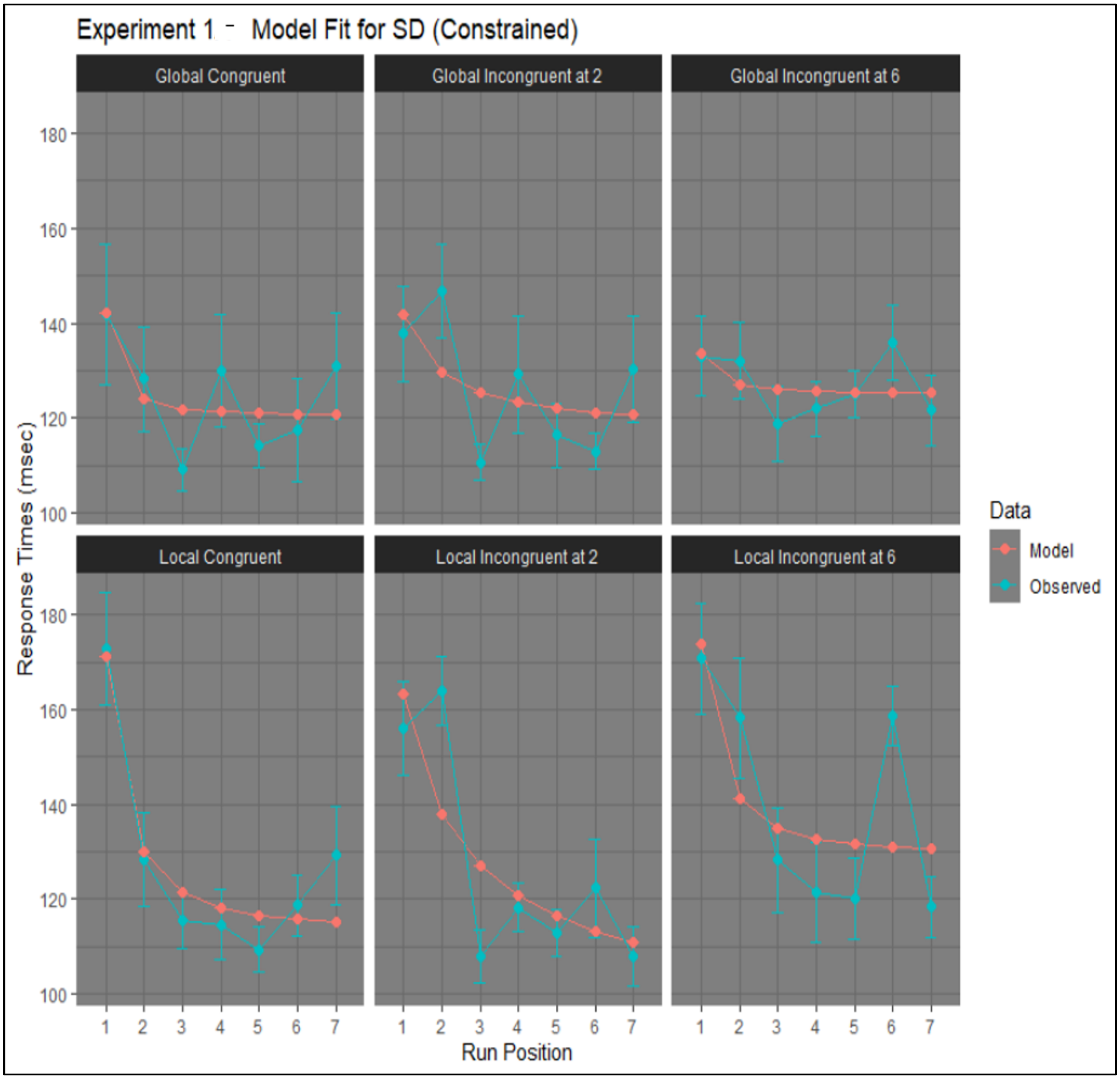

Figure 11. Model fits for mean SDs in Experiment 1. Predicted constrained and separate model values for mean SDs compared with participant data from experiment 1. Each prediction and participant data are separated by condition.

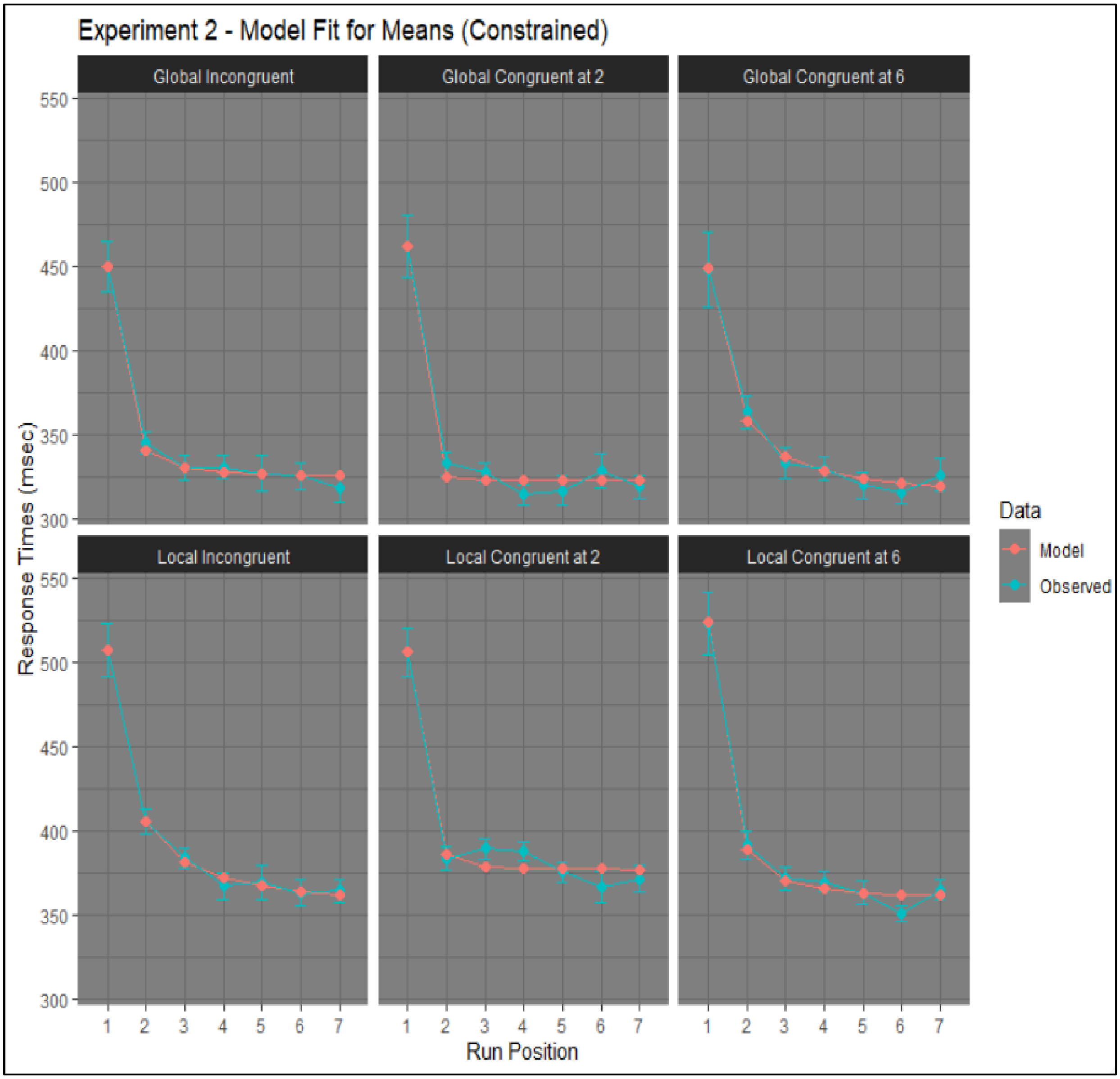

Figure 12. Model fits for mean RTs in Experiment 2. Predicted constrained and separate model values for mean RTs compared with participant data from experiment 1. Each prediction and participant data are separated by condition.

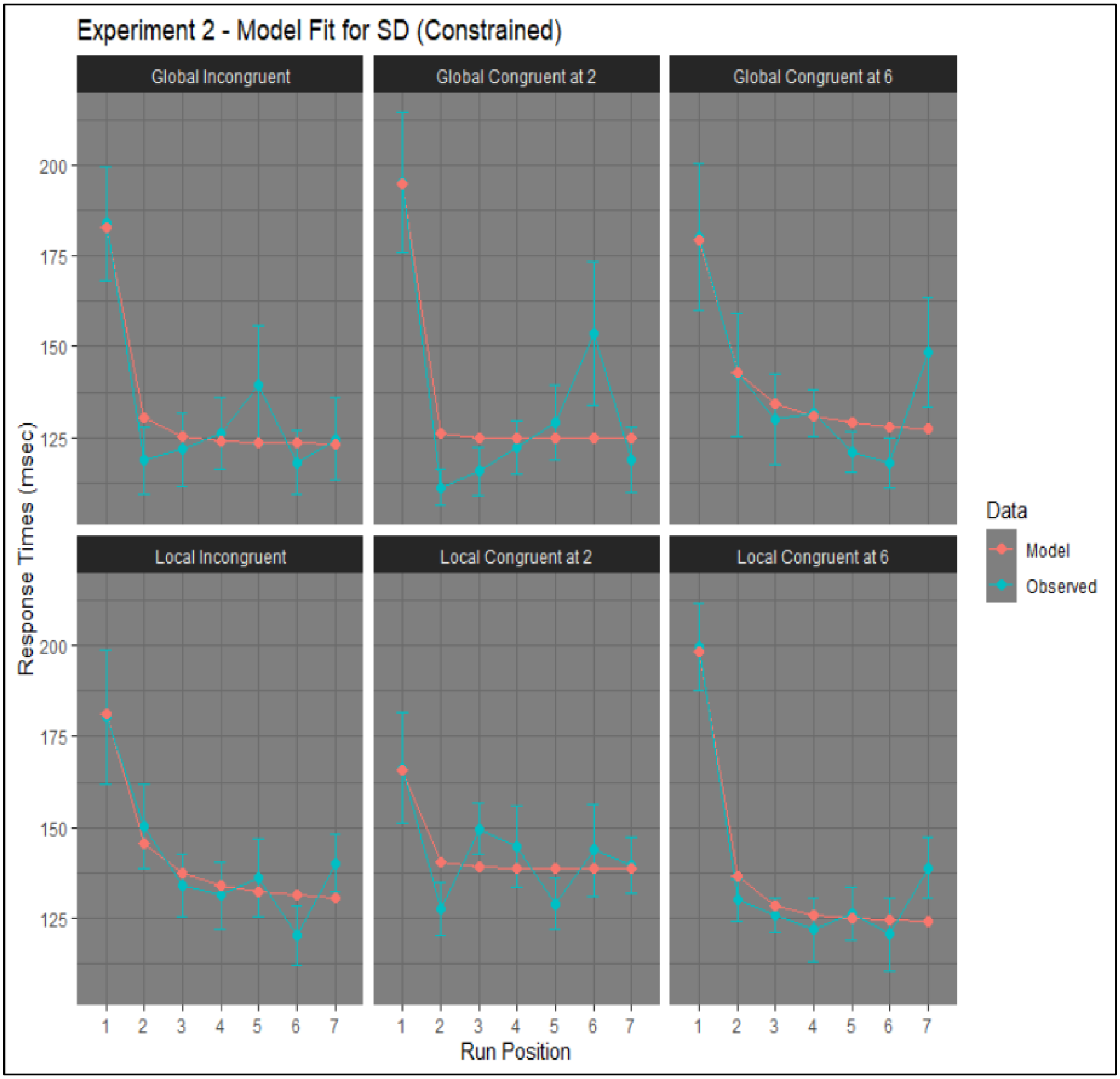

Figure 13. Model fits for mean SDs in Experiment 2. Predicted constrained and separate model values for mean SDs compared with participant data from experiment 1. Each prediction and participant data are separated by condition.

GENERAL DISCUSSION

Experiment 1 shows a decrease in RT with repeated tasks. This is similar to results from the second experiment in Lamb et al. (1998). Experiment 1 also shows that global interference persisted even after consecutive repeated tasks. Experiment 2 shows that global facilitation disappeared at position six but the reduction of global influence from position two to position six is not reliable. Due to the underpowered nature of experiment 2, it is difficult to make conclusive inferences regarding cognitive mechanisms' role with the level-repetition effect during task repetition and global precedence. However, these results from experiments 1 and 2 currently provide evidence that cognitive mechanisms have little influence on the level-repetition effect and do not reduce global precedence.

Overall, the fit of power-function speed-up model to our experiments and the model fit comparisons revealed that participants can learn from past tasks and switch strategies in our paradigm. The results were consistent to the conclusions made for experiments 1 and 2. However, Figure 13 presents conflicting evidence to the results of the model fit for experiment 2 and the conclusions drawn from experiment 2. Therefore, we tentatively conclude that switching to a more effective strategy within five repeated exposures did not reliably reduce the global level's influence.

Attention and Visual Processing

Presently, there are opposing theories regarding attentional processes and visual perception. Some studies claim that cognitive control occurs after attentional processing of salient items (e.g., Theeuwes, 1992) and responses are sometimes solely based on the salience-based processing (e.g., Schubo, 2009). Other studies argue that salience-based processing can be modulated by goals and intentions (i.e., cognitive mechanisms) at early visual processing stages (e.g., Bacon & Egeth, 1994; Folk et al., 1992; Kim & Cave, 1999).

The task shielding literature provides evidence that salience-based processing can be modulated by cognitive control (e.g., Reisenauer & Dreisbach, 2014). However, our current results suggest limits in selective attention's ability to reduce saliency's influence. Experiment 1 shows that selective attention cannot prevent some attentional processing of salient items while experiment 2 shows unreliable results. The reason and implication for selective attention's inability to reduce global precedence may be tied to the stage of processing used in our studies.

Stages of Processing

There are a number of factors that are worth considering for future studies. One important consideration is identifying the stages of processing (e.g., detection, identification or response) involved with global precedence. Our current studies are limited in determining the stages required to complete - and consequently affected by - the tasks. In other words, it is unclear which stages of processing determine global precedence and which of these stages are influenced by task shielding or additional attentional allocation. Knowledge regarding the stages of processing can help specify the cause for selective attention's inability to reduce global interference. Additionally, this information can further elucidate the relationship between the stages of processing involved and selective attention in the context of task shielding (i.e., strengthening cognitive control) and visual perception. This distinction between stages of processing is important to clarify because attentional influences and utility can change depending on the stage (Flowers & Wilcox, 1982; Taylor, 1977). Our tasks require participants to determine target presence while ignoring irrelevant information. Therefore, it is likely that several stages of processing may be involved in our studies and cause global interference. I first consider earlier perceptual stages.

Detection and Identification Stages

Detection and identification tasks produce responses at different stages of processing. Both tasks utilize attentional resources but detection requires less information and resources than identification (Broadbent & Broadbent, 1987; Kawahara et al., 2001). Identification tasks are more complex and require more time to deploy attentional resources to relevant stimuli (Kawahara et al., 2001). Although detection does not always require attention to focus on a task (Bravo & Nakayama, 1992), some detection tasks can utilize attention (Kawahara et al., 2001). Our tasks require quick attentional deployment and responses to briefly presented stimuli. Results from experiment 1 and 2 show high accuracy and fast RT performance. During the brief period of stimuli presentation, participants were able to quickly deploy attentional resources and gather enough information to respond correctly. This indicates that our tasks require detection (Broadbent & Broadbent, 1987; Kawahara et al., 2001). However, participants are also required to search each stimulus for a target. One strategy would be for participants to create a search template and respond based on whether the stimulus at focused level match the template. This could indicate that our tasks also require identification. Task shielding could affect all or only one of these processes.

One possible explanation for our results regarding task shielding’s inability to enhance filtration of irrelevant information could be from the difference in feature comparisons involved with Stroop-like interference and global interference. Cognitive mechanisms (i.e., selective attention) are able to modulate salience processing but selective attention has more trouble with shielding against, or reducing the influence of, closely related features. This could be due to a rise in task difficulty for distinguishing search templates (Schmidt & Zelinsky, 2017; Treisman & Gelade, 1980).

Previous task shielding studies (i.e., studies involving Stroop-like interference) only require simple search templates to compare easily discriminable features (colors vs. meaning); these qualities lead to easier inhibition of irrelevant information. By comparison, our tasks require a more complex search template to perform nuanced discrimination (specific letter at a specific level); these qualities lead to a more difficult or time-consuming process for selective attention to filter relevancy (Schmidt & Zelinsky, 2017). This would imply that global interference arises during the detection and identification stage (Schmidt & Zelinsky, 2017) and that selective attention may be limited in its ability to filter information when the visual search templates require discrimination based on level focus.

Response Stage

Another possibility is that the difficult set up and application of the search template causes a delay in filtrating relevancy. During this delay, some saliency-based processing could occur and bring about global interference during the decision-making or response stages. Because selective attention is unable to completely filter relevancy, the search templates would have activated the processing of salient and irrelevant or mismatched information. This would cause interference and slow decision-making or response processes by providing evidence for the other response (Hommel, 1995; Mewaldt et al., 1980). Alternatively, the difficult search template strategy may present a more difficult task in our experiments compared to past task shielding studies. As tasks difficulty increases, participants may become less confident in their decisions and have conflicting or slowed decision-making or response processes (Grubert & Eimer, 2015).

In summary, it is important to consider determining the stages of processing involved in our tasks to better understand and reduce global precedence. Global interference could arise during the identification stage (from the difficult and time-consuming filtration due to complex search templates) or during the decision-making or response stages (from response conflicts). Ultimately, it may be that the task - or stages involved with the task - determine or influence where global interference occurs. By determining the stage of processing in which global interference occurs, future studies can further examine the mechanisms surrounding global precedence. The current studies did not manipulate stages of processing and therefore these studies are limited in identifying the stages associated with global interference and which stages are affected by task shielding. However, these studies show that continuous or repeated level focus does not strengthen selective attention enough to reduce global precedence in tasks related to determining target presence with dichotomized (e.g., yes/no) responses. Therefore, our results provide restricted evidence that selective attention is unable to reduce global precedence - specifically global interference.

Data-limited vs. Resource-limited

Another important consideration is the idea of data-limited and resource-limited tasks. In short, data-limited tasks are when allocating additional processing resources does not improve task performance. Resource-limited tasks are when task performance improves with increasing amounts of processing resources (see Norman & Bobrow, 1975 for review). In our studies, performance started with relatively long RTs, but then quickly improved, reaching asymptote in later run positions. It may be that initially, our tasks were resource-limited; performance improves as more attention is allocated to the task. Yet after consecutive exposures, the tasks become data-limited; performance does not improve from further allocation of attention to the task. These performance trends suggest that our paradigm shifts from resource-limited to data-limited across a run. After some repeated exposure, participant either stop allocating additional attentional resources to the task or additional resources no longer help with performance. Our paradigm may strengthen selective attention but the influences of resources and resource allocation are minimized near the end of each run.

Exposure Duration

One important factor to consider for future studies is exposure duration. Experiment 3 provides exploratory data on the impact of exposure duration. This experiment is identical to experiment 1 with the exception that the presented stimulus remained on the screen until responses were given. Results shows that participants were unable to reduce the influence of the irrelevant level for both globally focused and locally focused conditions (see Appendix A for results and further discussion).

Congruence

Another important consideration for future studies is the possible confound of congruence. In our studies, we did not separate the influence of congruence from letter relevance. Reduced task performance may partly be due to a congruence change (e.g., change from congruent to incongruent) instead of the shift in target presence for the irrelevant level (e.g., global letters changing between target and non-target letters). An argument against this claim is that the congruence change had different effects on performance in experiment 1 than in experiment 2. In experiment 1, the congruence changes interfered and reduced performance while the congruence changes in experiment 2 facilitated or increased performance. However, it is still possible that the congruence change indirectly causes these effects by drawing attention to the changed (i.e., irrelevant) level. Therefore, one possible direction for future studies is controlling for this factor and reexamining selective attention's influence on the level-repetition effect and global precedence.

Alternative Interpretations for Instances

An important issue and limitation to address with our model fit is that our studies are limited in identifying the instances being stored. Task shielding literature would indicate that previous exposures are providing instances of following task rules. The mechanism activation hypothesis suggest that previous exposures are providing instances of the most recently activated mechanisms. A third possibility is that previous exposures are providing instances of congruence type (congruent, or incongruent). This would provide an alternate explanation for the interfering or facilitating effects in our studies. It may be that participants encode instances based on the congruence type in previous tasks and switch strategies accordingly. This congruence change causes participants' attention to be attracted to the irrelevant level. Furthermore, it is unclear whether these instance-based strategies rely on non-cognitive processes or cognitive processes. In other words, participants may be using processes that do not require voluntary cognitive mechanisms when they switch to instance-based strategies and the congruence changes (i.e., study manipulations) cause participants to revert back to voluntary cognitive processes. This switch to the voluntary cognitive processes - in addition to the congruence change - may be the reason for the difference in performance at the critical position compared to previous positions. We aim to investigate these issues in future studies.

Number of Exposures

The results from our experiments and the model fit comparisons suggest that task- or goal-driven participants are unable to use cognitive mechanisms such as selective attention to prevent non-cognitive mechanisms from processing salient irrelevant information. However, Logan's instance theory of automatization provides an alternate interpretation. This theory indicates that participants require a number of exposures before switching to instance-based strategies. It may be that participants need the first couple of exposures (two - seven in our studies) to switch strategies and rely on task rule sets for task completion; task shielding can only occur and strengthen after this switch. Therefore, our design may only present enough exposures to switch strategies but not enough exposures to strengthen task shielding. Future studies can address this by including more exposures and comparing the interference effect between positions after an asymptote is reached.

CONCLUSIONS

Visual perception is an important aspect in many daily activities (e.g., driving, watching TV, etc.). These activities sometimes require fast decisions or actions that rely on information based on the visual perception of items involved with the activities. Biases allow for fast visual processing but these biases can often be wrong and promote inaccurate perceptions and decisions. Cognitive mechanisms can adjust these biases but the limitations of adjusting or controlling these biases have not been fully explored. To develop methods and strategies that optimize these abilities, it is important to understand the limitations of cognitive mechanisms such as selective attention and visual biases like global precedence. Our method and paradigm investigate the fluidity and limitations of strengthening selective attention by examining its ability to focus on or suppress information within specific categorical dimensions. Specifically, we looked at whether strengthening selective attention can reduce global interference. The current findings seem to show support for Lamb and colleagues' claim. Strengthening selective attention does not reduce global interference. While all these studies are limited in their claims, they pose interesting questions and foundation for future studies.

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APPENDIX A: SUPPLEMENTAL EXPERIMENT

Experiment 3

Experiments 1 and 3 used the same stimuli, design and procedure but differed in stimulus duration. Within experiment 3, each stimulus remained in view until participants gave a response. One potential issue is that participants may have a complete visual representation of the entire hierarchical letter before making a response, thereby perceiving both the global and local level. Perceptual load theory suggests that attention can spill over to irrelevant information with simple stimuli or tasks - even with an efficient selective attention. This could be problematic as interference would always occur, regardless of the strength of selective attention. Experiment 1 addresses this issue. The stimulus duration in experiment 1 allows for a limited amount of time to perceive the stimulus, forcing participants to attend only to the relevant information and reducing the chance for attention to spill over to irrelevant information.

Participants

There were 41 participants in experiment 3. Participants were recruited from the University of South Florida SONA pool and ran in IRB-approved protocol. Participants received extra credit for their participation. Three participants in experiment 3 were removed due to having high proportion of errors. Thus, we examined the data of 38 participants.

Results

Congruent or baseline runs show a generally logarithmic decrease in RTs throughout a run for both globally focused and locally focused conditions (see figure 11).

Relative to baseline, position two had elevated RTs with an incongruent stimulus for both locally focused conditions(Mean difference = 104, SE = 11.14); t (37) = 9.32, p <.001, partial eta squared = .70, and globally focused conditions (Mean difference = 46, SE = 8.5); t (37) = 5.37, p <.001, partial eta squared = .44.

Position six also had elevated RTs with an incongruent stimulus for both locally focused conditions (Mean difference = 136, SE = 13.15); t (37) = 10.36, p <.001, partial eta squared = .74 and globally focused conditions (Mean difference = 34, SE = 13.26); t (37) = 2.55, p = .02, partial eta squared = .15.

No significant differences were found for the comparisons between the interference effects at position two and position six for either globally focused or locally focused conditions.

Discussion

It is worth noting the different RT functions in the incongruent conditions compared to the congruent conditions between experiments 1 and 3. Additionally, the globally focused conditions had different responses to an incongruent stimulus at position six than the locally focused conditions in both experiments (see figure A). In experiment 3, the interference effect was similar at position six as the interference effect at position two for globally focused conditions. Yet the interference effect at position six was larger than the interference effect at position two for locally focused conditions. In experiment 1, globally focused conditions had a small interference effect at position two but no interference effect at position six. At position six, locally focused conditions had similar interference effects as position two.

As stated earlier, the difference of RT functions with incongruent conditions between experiments 1 and 3 may be explained by the perceptual load theory and worth investigating in future studies.

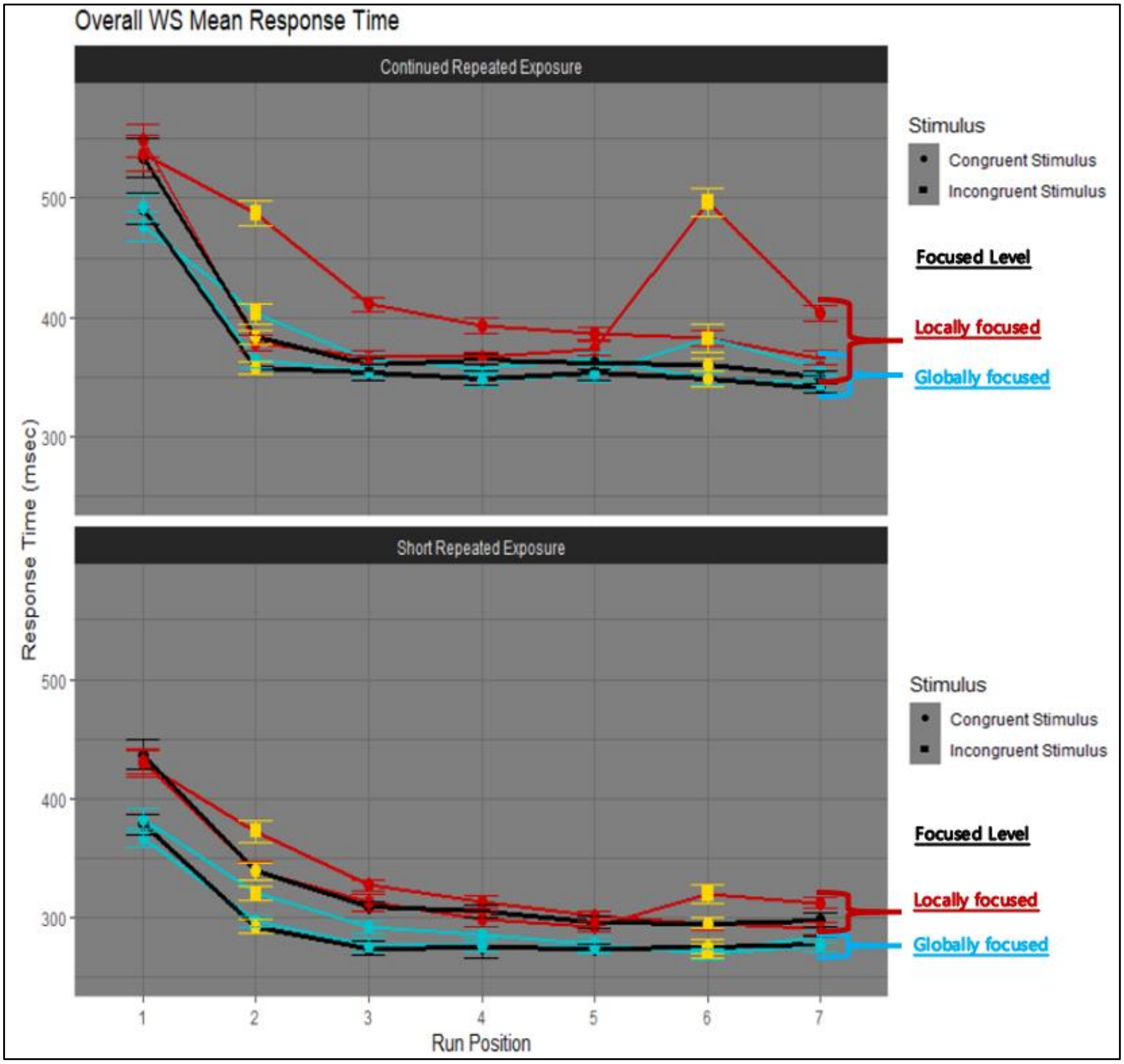

Figure A. RT comparison between Experiments 1 and 3. RT results of experiment 3. (Top) compared to results of experiment 1 (Bottom); Highlighted data points represent concerned or examined observations); black lines represent congruent runs; error bars represent within subject standard errors.

APPENDIX B: SUPPLEMENTAL MODEL FIT DATA

Trimmed Data Results for Experiment 1

Locally Focused Runs. Relative to baseline, position two had significantly elevated RTs (i.e., slower responses) with an incongruent stimulus (Mean difference = 35, SE = 9.83); t(29) = 3.51, *p* = .002, Cohen's *d* = .62. Position six also had significantly elevated RTs with an incongruent stimulus (Mean difference = 28, SE = 8.16); t(29) = 3.40, *p* = .002, Cohen's *d* = .29. There was no significant decrease in interference effects from position two to position six (Mean difference = 7, SE = 10.13); t(29) = .67, p = .51, Cohen's *d* = .02.

Globally Focused Runs. Relative to baseline, position two had significantly elevated RTs with an incongruent stimulus. (Mean difference = 25, SE = 7.47); t(29) = 3.27, *p* = .003, Cohen's *d* = .44. Position six did not have a significant elevation in RTs with an incongruent stimulus (Mean difference = 0 SE = 8.49); t(29) = .02, *p* = .98, partial eta squared = 0. Lastly, there was no significant decrease in interference effects from position two to position six (Mean difference = 25, SE = 13); t(29) = 1.91, p = .07, Cohen's *d* = .34.

Trimmed Data Results for Experiment 2

Locally focused runs. Relative to baseline, position two had significantly lower RTs (i.e., faster responses) with a congruent stimulus (Mean difference = 22, SE = 9.85); t(19) = 2.26, *p* = .04, Cohen's *d* = .51. Position six did not have significantly lower RTs with a congruent stimulus (Mean difference = 14, SE = 10.1); t(19) = 1.41, *p* = .17, Cohen's *d* = .32. There was no significant decrease in facilitation effects from position two to position six (Mean difference = 8, SE = 10.9); t(19) = .64, p = .47, Cohen's d = .17.

Globally focused runs. Relative to baseline, RTs were not significantly lower with a congruent stimulus at position two (Mean difference = 10, SE = 8.1); t(19) = 1.19, p = .25, Cohen's d = .27, or position six (Mean difference = 5, SE = 8.1); t(19) = .64, p = .53, Cohen's d = .14. There was also no significant decrease in facilitation effects from position two to position six (Mean difference = 4.5, SE = 10.17); t(19) = .44, p = .66, Cohen's d = .10.

Trimmed Data Model Fit Results in Experiment 1 and 2

Goodness of Fit. For every condition in experiments 1 and 2, overall r^2 values had little to no differences between the separate and constrained model fits; therefore, only the constrained fit values are reported. For mean RTs, r^2 was above .95 in every condition for both experiment 1 and 2 (see tables 1 and 2). Experiments 1 and 2 both had lower r^2 for mean SDs compared to mean RTs. Experiment 1 also had worse r^2 values than experiment 2; r^2 for mean SDs were around .3 - .9 for experiment 1 and around .6 - .9 for experiment 2.

Additionally, overall *rmsd* values were similar between the separate and constrained fits for every condition in experiments 1 and 2; therefore, only the *rmsd* values for the constrained model fit are reported. For mean RTs, *rmsd* were relatively small (about 4 -17 msecs for data that ranged between 250 – 550 msec). For mean SDs, *rmsd* values were comparably larger (between 9 - 26 msec for data that ranged between 100 - 180 msec) in both experiments 1 and 2.

Rate of Learning Parameter. For every condition in experiments 1, separate and constrained fits for mean RTs had similar rate of learning values. For experiment 2, the "incongruent" ("c" difference = .668) condition for globally focused runs and the "congruent at two” condition for both globally focused runs (“c” difference = .630) and locally focused runs (“c” difference = .629) had the largest differences.

The separate and constrained fits for mean SDs produced relatively different rate of learning values in multiple conditions for both experiments 1 and 2. For experiment 1, the “congruent” (“c” difference = 1.035) condition for globally focused runs, and the “incongruent at six” (“c” difference =.896) condition for locally focused runs had large differences in rate of learning values between separate and constrained model fits. For experiment 2, the “incongruent” (“c” difference = 2.842) and “congruent at two” (“c” difference = 1.786) conditions for globally focused runs and the “congruent at two” (“c” difference = 2.067) and “congruent at six” (“c” difference = 2.8) conditions for locally focused runs had relatively large differences. Notably, the “incongruent” condition for globally focused runs and “congruent at two” for both globally focused and locally focused runs had reached the ceiling of our parameter constraints, indicating that these differences are likely to be higher.