Measuring Attention Control Abilities with a Gaze Following Antisaccade Paradigm

by

Jade Noelani Lee Yonehiro

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved April 2018 by the
Graduate Supervisory Committee:

Nicholas D. Duran, Chair
Mary H. Burleson
Zachary Horne

ARIZONA STATE UNIVERSITY

May 2018

ABSTRACT

Social gaze-following consists of both reflexive and volitional control mechanisms of saccades, similar to those evaluated in the antisaccade task. This similarity makes gaze-following an ideal medium for studying attention in a social context. The present study seeks to utilize reflexive gaze-following to develop a social paradigm for measuring attention control. Two gaze-following variations of the antisaccade task are evaluated. In version one, participants are cued with still images of a social partner looking either left or right. In version two, participants are cued with videos of a social partner shifting their gaze to the left or right. As with the traditional antisaccade task, participants are required to look in the opposite direction of the target stimuli (i.e., gaze cues). Performance on the new gaze-following antisaccade tasks is compared to the traditional antisaccade task as well as the highly related ability of working memory.

DEDICATION

To Casey, for putting up with my terrible neglect and perpetual state of stress in the last year. I couldn’t have done it without you.

ACKNOWLEDGMENTS

We would like to thank Gene A. Brewer and Randall W. Engle for providing the working memory and traditional antisaccade tasks. Funding by ASU's Professional Student Association's JumpStart Grant Program is gratefully acknowledged.

TABLE OF CONTENTS

Page

APPENDIX

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Chapter 1

INTRODUCTION

At any given moment our environment is filled with far more information than we can observe at once. With a seemingly infinite number of incoming signals, we need some way to decide what we should pay attention to. To this end, attention control allows us to selectively attend to stimuli in the environment (Posner & Rothbart, 2007). Attention control is typically studied by measuring a person's ability to orient attention "at will" in the face of distracting stimuli (Unsworth, Schrock, & Engle, 2004). To date, the use of simple stimuli (e.g., flashes of light or basic geometric shapes) to capture attention has dominated the field of attention research; however, the generalizability of such stimuli has been the subject of some critique (Kingstone, Laidlaw, Nasiopoulos, & Risko, 2016). Joint attention, specifically the tendency to reflexively align one's attention with another person via gaze-following, may provide a unique opportunity to measure attention control in a more complex social context. Despite its potential, little is known about how joint attention abilities fit into current models of attention control. The present study aims to bring together research on gaze-following and traditional models of attention control to evaluate the potential of using gaze cues as stimuli for measuring attention

Chapter 2

THEORETICAL BACKGROUND

Attention Control

Two contrasting processes drive attention control: bottom-up and top-down selection. Bottom-up or stimulus-driven selection refers to the passive and involuntary orienting of attention to salient and potentially important stimuli in the environment (Connor, Egeth, & Yantis, 2004). Top-down or goal driven selection refers to the volitional orienting of attention to stimuli that are relevant to a person's current behavior or intentions (Theeuwes, 2010). Although top-down selection is typically associated with attention control, both play important roles in the way we study attention abilities.

Bottom-up selection is responsible for orienting attention to salient stimuli regardless of the intentions of the observer (Connor et al., 2004). For example, if there were a sudden flash of light while you were reading, you would automatically look towards the source of the flash. This behavior has a significant survival purpose. Salient features such as stark color and geometric contrast could be a food source, while sudden movement or sounds could indicate a predator attack (Connor et al., 2004). For the modern-day human, however, salient bottom-up distractors can lead to difficulties with maintaining attention on important tasks (van Zoest & Donk, 2003).

Despite their automatic nature, bottom-up processes are not in complete control of our attention. Top-down processes allow us to orient attention "at will" to stimuli that are relevant to our current goals or behaviors (Theeuwes, 2010). Suppose the flash of light from the previous example came from an unimportant source like a camera flash. Top-down selection would allow you to ignore successive flashes and return your focus to reading. Top-down control typically occurs after attention has been captured by a bottom-up stimulus. This is because top-down selection requires recurrent feedback processes to modulate attention selection – a process reliant on working memory (Shipstead, Harrison, & Engle, 2015; Theeuwes, 2010).

Working Memory and Attention

Without the ability to hold our goals in mind, we would not be able to orient attention in a way that helps us achieve them. Working memory, the ability to temporarily maintain and manipulate goal-relevant information, is responsible for biasing top-down attention towards goal-relevant stimuli through the maintenance of attentional priorities (Shipstead et al., 2015; Morey et al., 2012). Working memory goal maintenance influences attention at two levels: (1) inhibiting a bottom-up response that runs counter to the task goal and (2) planning and executing a top-down response in line with the current task goal (Roberts, Hager, & Heron, 1994; Morey et al., 2012; Unsworth et al., 2004). But the relationship between working memory and attention is not a one-way street. Just as attention needs working memory to select what to focus on, working memory needs attention to continually provide goal-relevant information and feedback in order to update the current active goal (Conway et al., 2005). Because of this bi-directional relationship, attention and working memory are often studied in parallel. The overlap between these constructs is clearly evident when one examines the paradigms used to probe attention control abilities.

Attention control is usually measured with tasks that pit bottom-up and top-down selection against each other. These paradigms require a person to override a reflexive orienting response (bottom-up selection) and allocate attention to an alternative goal-related location (top-down selection via working memory goal maintenance) (Heitz & Engle, 2007; Posner & Rothbart, 2007). As described earlier, working memory, specifically the goal maintenance aspect, is vital to attention control. As such, individual differences in working memory ability can heavily influence performance on attention control tasks. Individuals with high working memory ability (high-spans) resolve competition between bottom-up and top-down selection quickly (Engle, 2002; Heitz & Engle, 2007; Shipstead et al., 2015; Theeuwes, 2010), while individuals with low working memory abilities (low-spans) often have difficulty resisting bottom-up selection (Unsworth et al., 2004). Low-spans tend to make more errors and display slower response times on attention control tasks than those with higher working memory abilities (Conway et al., 2005; Conway, Kane, & Engle, 2003). This is likely due to the fact that low-span individuals are more susceptible to goal neglect when attention is captured by a strong distractor (Unsworth et al., 2004; Morey et al., 2012; Kane & Engle, 2003). When a strong bottom-up distractor is present, low-spans individual's goal representations are weakened. Ultimately, this results in a delayed or even a complete failure to execute top-down control (Unsworth et al., 2004).

The relationships between working memory and attention control has been heavily studied in the cognitive literature; however, research on social cognition has largely ignored this relationship when evaluating attention control in the context of social interaction. Critically, this relationship has been overlooked by researchers looking to develop "real-world" measures of attention control. If psychologist aim to develop increasingly "real" measures of cognitive functions, any new or modified attention control task should take this relationship into account. Doing so will help elucidate the relationship between working memory and attentional control across a range of bottom-up and top-down constraints.

Social Attention

Recently, researchers have begun to question the generalizability of traditional cognitive tasks that use simple stimuli (e.g., flashes of light or basic geometric shapes) to elicit bottom-up attention selection (Driver et al., 1999; Frischen, Bayliss, & Tipper, 2007; Friesen, Ristic, & Kingstone, 2004; Langton, Watt, & Bruce, 2000; Risko, Laidlaw, Freeth, Foulsmham, & Kingstone, 2012). Such stimuli are considered to be removed from the more real-world domains where attention is routinely employed, namely in social contexts. In response to this critique, many researchers have begun investigating how social cues influence the allocation of attention. Joint attention, the ability to share attention with another person, has become a popular medium for such investigations.

Joint attention is the ability to align our own attention with another person by following their various social cues. These cues include low-level behavioral markers of attention such as the direction of a person's eye gaze, their head turns, and their gestures (Mundy & Newell, 2007). Early research on joint attention suggests that the alignment of attention to the gaze cues of another person, referred to as gaze-cueing or gaze-following, occurs reflexively (i.e., in a bottom-up fashion) (Driver et al., 1999; Friesen & Kingstone, 1998). This finding is robust, replicating across various levels and types of gaze cue stimuli. These stimuli range from schematic-static eyes (sketches of eyes looking left or right) to dynamic real faces (videos of real people's gaze shifts). Some paradigms even use faces displaying various emotions (Wolohan & Crawford, 2012). To date, most gaze-cueing research has focused on simply identifying whether or not various gaze-stimuli trigger reflexive bottom-up orienting. This is no small task, as even traditional stimuli range in their effectiveness. For example, a sudden onset peripheral cue, like a flash of color in your periphery, will elicit reflexive orienting while centrally presented directional cues like arrows do not. (Langton et al., 2000).

Researchers have repeatedly found gaze cues to reliably elicit bottom-up orienting (Frischen et al., 2004; Driver et al. 1999; Ricciardelli, Bricolo, Aglioti & Chelazzi, 2002). In other words, gaze cues appear to trigger involuntary orienting of the observer. A few researchers have even found evidence that gaze-cues are a stronger bottom-up stimulus than centrally presented directional cues and peripheral cues (Friesen et al. 2004; Marino, Mirabella, Actis-Grosso, Emanuela & Ricciardelli, 2015); however, research which directly compares gaze and traditional stimuli is sparse and warrants further investigation. There are two pivotal studies that directly compare the bottom up orienting abilities of these types of stimuli.

Marino, Mirabella, Actis-Grosso, Bricolo, and Ricciardell (2015) tested the influence of gaze cues on a countermanding task. This task measures the ability to suppress reflexive saccades but omits the need to execute any effortful allocation of attention. In this study, participants were presented with social (gaze cues) and nonsocial (peripheral flash) cues. In half of the trials participants were instructed to follow the cues (no-stop trials). In the other half, they were instructed to suppress the reflex to follow the cue and continue to look directly (i.e., inhibit the response to look only) at the center of the screen until the end of the trial (stop trials). Marino and colleagues found that participants took longer to suppress their saccades in stop (don't look) trials using social stimuli than in those using nonsocial stimuli. These findings suggest that suppressing saccades in response to a gaze cue is more difficult than in response to non-social cues. Though promising, this studies only evaluated one aspect of attention control – inhibition of bottom-up orienting.

Friesen and colleagues (2004) evaluated the bottom-up orienting strength of gaze and arrow cues. They modified the Posner cueing paradigm (Figure 1) to include either schematic gaze cues or equivalent arrow cues. In their paradigm, participants were instructed to simply press a button indicating which target appeared (*T* or *F*) and were not provided any information about the gaze stimuli. They found that participants would orient in the direction of gaze, but not arrows cues, when both cues were counterpredictive to a target's location. The authors posit that, although both cue types can be used to direct attention, gaze cues do so more reflexively when centrally presented. These findings, and others like them (see Frischen et al., 2007; Mulckhuyse & Theeuwes, 2010; and Langton, Watt, & Bruce, 2000 for review; also, Friesen & Kingstone, 1998; Mundy & Jarrold, 2010), repeatedly demonstrate that gaze cues can be used to trigger bottom-up selection in a similar manner to traditionally used stimuli (e.g., peripheral flashes, etc.). This suggests that gaze cues are an effective medium for studying attention; however, more research is needed to evaluate how variations in gaze stimuli modulate the way people allocate their attention.

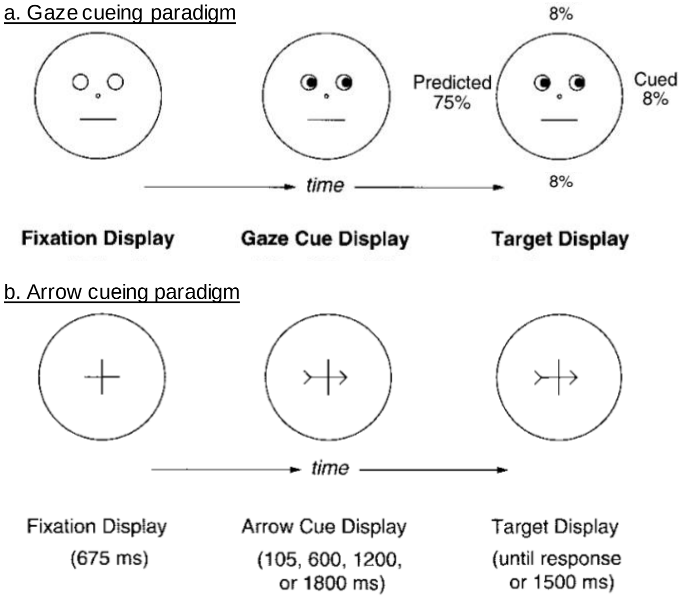


Figure 1. Trial procedure for Friesen, Ristic, and Kingstone (2004) (a) gaze cue and (b) arrow trials. The target letter appeared in the direct opposite side of the cued location 75% of the time, the cued location 5% of the time, and the other two locations 5% of the time.

Despite robust evidence for the reliability of gaze cues to involuntarily orient attention, variations in gaze stimuli can have major impacts on this effect. Risko and colleagues' (2012) review of social stimuli demonstrated that changes in the "realness" of stimuli greatly impacts its bottom-up orienting strength. For instance, schematic faces elicit a larger orienting effect than real faces and dynamic gaze cues elicit stronger orienting responses that static cues. These findings suggest that not all gaze stimuli are created equal. We have little knowledge regarding the effect of various levels of gaze stimuli on the use of gaze cues for psychometric purposes (i.e., for measuring attention control). If the goal of social attention research is to move towards a more “real-world” evaluation of cognitive abilities, more research is needed to evaluate the orienting potential of various gaze-stimuli for measuring attention control. In addition, research on gaze cues has largely overlooked the broader literature on attention control. Critically, it has left the relationship between attention control and working memory largely unexplored. The present study aims to shed further light on these issues.

Chapter 3

THE PRESENT STUDY

This study aims to evaluate the potential of using gaze cues to measure attention control relative to traditional measures. The present study extends previous research on gaze stimuli in three ways. First, the traditional attention control task, the antisaccade, has been modified to make the bottom-up stimuli more social in nature using two levels of gaze stimuli. Specifically, these tasks require participants to override the reflex to look in the direction of another's eye gaze and intentionally look to an alternative location – requiring top-down control based on instructions given before the trial. This study uses both still images (i.e., static stimuli) and videos (i.e., dynamic stimuli) of a real person's gaze shifts. Second, performance on the gaze-following paradigms will be directly compared to the original antisaccade task where the bottom-up stimulus is a simple flash. Thus far, gaze cues have been compared in inhibition tasks, tasks using arrow cues, or in young children who do not process social cues in the same way as adults (see Nummenmaa & Calder, 2009). Third, participants were administered measures of working memory to probe the degree to which working memory ability supports top-down control in resisting distraction from increasingly complex and social bottom-up stimuli.

Hypotheses

H1. Humans tend to prioritize and orient more reliably to social stimuli than simple stimuli (Friesen et al., 2004b). Furthermore, dynamic gaze stimuli have been found to elicit stronger orienting than static gaze stimuli (Risko et al., 2012). Thus, it is predicted that the dynamic gaze-following AST (antisaccade task) will be more difficult to perform than the static and traditional AST. Task difficulty was assessed using participant's accuracy rates and response time, such that lower accuracy rates and longer response times indicate greater task difficulty (Shipstead, Harrison, & Engle, 2015; Heitz & Engle, 2007; Theeuwes, 2010). To this end, there are three predictions:

H1a. Accuracy rates will be lower in the gaze-following antisaccade tasks than in the traditional antisaccade task.

H1b. Response times will be longer in the gaze-following antisaccade tasks than in the traditional antisaccade tasks.

H1c. Accuracy rates will be lower and response times will be longer in the dynamic gaze-following antisaccade task than the static gaze-following antisaccade task.

H2. Working memory is responsible for biasing top-down attention towards goal-relevant stimuli and minimizing the effects of goal irrelevant stimuli (Heitz & Engle, 2007). As such, individual differences in working memory ability can be used to predict performance on attention control tasks (Conway et al., 2005). Individuals who score poorly on measures of working memory tend to make more errors and display slower response times on attention control tasks than those with high working memory abilities (Conway et al., 2005; Conway et al., 2003; Unsworth et al., 2004). If gaze cues trigger bottom-up orienting similar to peripheral cues, it is hypothesized that working memory scores will be related to performance on all three of the ASTs. Specifically, gaze cue tasks will impose higher bottom-up demands and rely more heavily on working memory to orient attention to the goal-related location (Marino et al., 2015). Furthermore, Risko and colleagues (2012) found that dynamic gaze cues elicit stronger bottom-up orienting than static cues; therefore, there should be differential recruitment of working memory ability across the three AST types. Specifically:

> **H2a.** Individuals with higher scores on a working memory assessment will demonstrate higher accuracy rates on the antisaccade tasks, while those with low scores will have lower accuracy rates.
>
> **H2b.** Individuals with higher scores on a working memory assessment will have faster response times on the antisaccade tasks, while those with low scores will have longer response times.
>
> **H2c.** If H1a-c is confirmed, such that the dynamic task is shown to be the most difficult of the three antisaccade tasks, it is predicted that working memory ability will be most related to performance on the dynamic gaze-following antisaccade task, relative to the static and traditional antisaccade task

Chapter 4

METHODOLOGY

Participants

142 undergraduate students were recruited from Arizona State University's subject pool. Five were removed for not following instructions and 13 were removed due to a computer error, resulting in a final sample of 124. There were 99 females, 24 males, and one participant who did not wish to provide a gender identification. Their mean age was 22.24 years (SD = 3.60). Participants were compensated with either a $15 gift card or credit towards course requirements.

Procedure

Participants were randomly assigned to one of two gaze-following groups: static (n = 59) or dynamic (n = 64) gaze cues. Due to concerns about practice effects in antisaccade tasks, assignment to gaze-following groups was between-subjects (Unsworth et al., 2004; Hutton, 2008). After completing the gaze-following AST, participants completed two working memory tasks (Operation Span and Symmetry Span tasks), and the traditional AST.

Tasks Descriptions

Traditional Antisaccade Task In the traditional AST (Kane, Bleckley, Conway, & Engle, 2001), participants complete two consecutive trial types: pro- and anti-saccade trials. In the prosaccade trials (Figure 2a) a stimulus is flashed in the participant's peripheral vision on either side of a screen. Participants look at the side of the screen where the stimulus flashed. A target letter (P, B, or R) appears briefly on the same side as the flash and participants record which letter they saw. Prosaccade trials are easy to complete, as the tendency to look towards the flashed stimuli is reflexively driven by bottom-up selection (Unsworth et al., 2004). Researchers have demonstrated that high- and low-span individuals score equally well in the prosaccade trials (Conway et al., 2003; Unsworth et al., 2004).

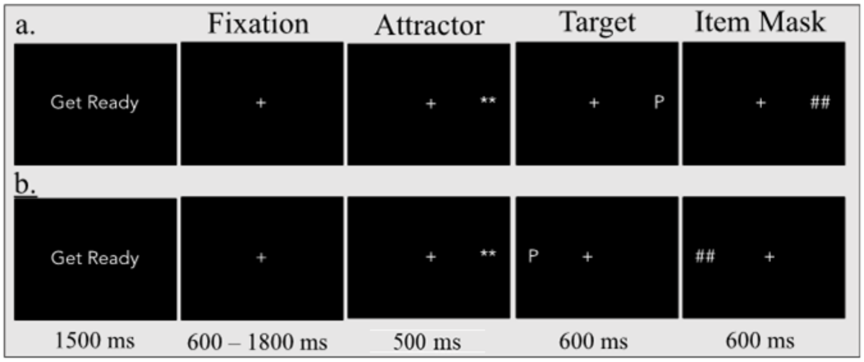


Figure 2: Procedure for Traditional Antisaccade Trials

In the antisaccade trials the same flash appears; however, the target letter appears on the opposite side as the flash (Figure 2b). Participants are instructed to suppress the automatic response to look at the flashed stimulus and instead look to the opposite side of the screen and report the letter they see. Thus, the antisaccade trials provide the competition between bottom-up and top-down selection required to measure individual differences in attention control (Unsworth et al., 2004). Individuals with low-span abilities show more difficulty with the task, demonstrating slower response times and making more incorrect responses than individuals with high-working memory (Conway et al., 2003; Unsworth et al., 2004). Participants completed 10 practice and 60 real antisaccade trials.

The AST was chosen as the attention control measure for two reasons. First, modifying this task allows for the direct comparison of a strong traditional bottom-up stimulus, peripheral flashes, to gaze cues. Second, the AST has been shown to reliably measure the conflict between bottom-up and top-down responses (Hutton & Ettinger, 2006).

Gaze-cueing Antisaccade Task Two gaze cueing versions of the AST were developed, the static and dynamic AST. Both versions were identical to the original task except for the stimuli used for the fixation and attractor screens (Figure 3). In the static-gaze version, the fixation screen was replaced with a photo of a woman looking straight ahead. The attractor screen was replaced with an image of the woman looking either left or right. As with the original task, the direction of the gaze was counterbalanced and randomized across trials. In the dynamic-gaze version, the fixation screen was also replaced with a photo of a woman looking straight ahead. However, the attractor was replaced with a video of the woman's eyes shifting to the left or right. Participants completed 10 practice and 60 real gaze-cueing antisaccade trials, per their group assignment.

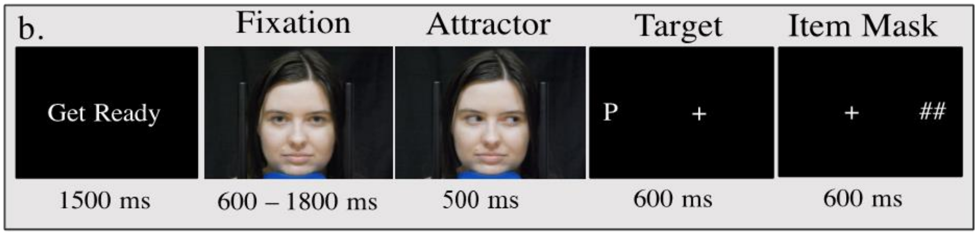


Figure 3: Procedure for Gaze-Following Antisaccade Trials

Operation Span Task In the Operation Span task (OSpan), participants must remember a series of letters while solving math equations (Figure 4). A to-be remembered letter is presented for 800 ms, followed by a math equation. Participants must identify if the solution provided for the math equation is true or false before they can move on to the next letter. Each trial block randomly displays 3-7 to-be-remembered letters with math equation judgments made between each presentation. At the end of the trial, participants must identify the letters they saw in the order in which they appeared using a 3x4 letter array. OSpan performance is assessed by totaling the number of letters correctly identified for trials with at least 80% accuracy on the trial math equations. Participants completed 10 OSpan trial blocks.

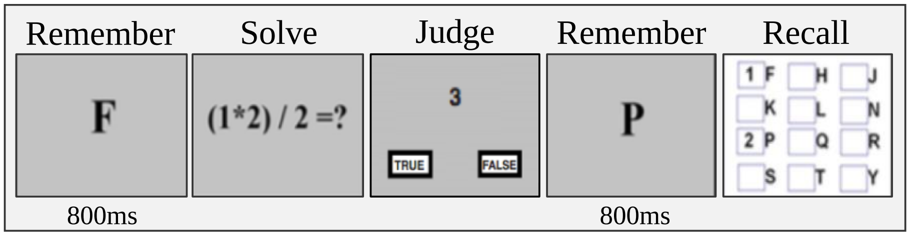


Figure 4: Procedure for Operation Span Task Trials (image not to scale).

Symmetry Span Task In the Symmetry Span (SSpan), participants are presented with a 4 x 4 grid with one random red colored square (Figure 5). Next, participants must judge if a shape is symmetrical along the vertical axis. Each trial block randomly displays 3-5 to-be-remembered red boxes with symmetry judgments made between each presentation. At the end of the trial, participants must identify the location of the red squares they saw in the order in which they appeared on a 4x4 grid. SSpan performance is assessed by totaling the number of letters correctly identified in order. Participants completed 8 SSpan trial blocks.

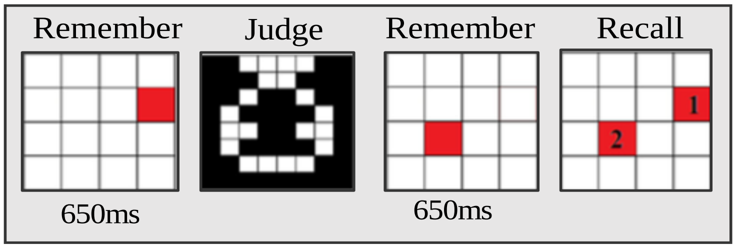


Figure 5: Procedure for Symmetry Span Task Trials (image not to scale).

Chapter 5

DATA ANALYSES AND RESULTS

Data Preparation

Outliers Prior to running the analyses all trials in which response times were either (1) below 100ms or (2) three standard deviations above the response time mean were removed. This removed score pronounced deviations and were normalized using a log-10 transformation. Z-scores were calculated and used for both Ospan and Sspan scores so they could be combined to create a composite working memory score (Conway et al., 2005).

Statistical Analyses and Accessibility All analyses were run using the R statistical software version 3.4.3 (R Core Team, 2013). Linear mixed-effect models were run using lme4 package version 1.1-15 (Bates, Maechler, Bolker, & Walker, 2015) and the lmerTest package version 1.0 (Kuznetsova, Brockhoff, & Christensen, 2017). The coefficients of each predictor, standard error, p-value, and estimated R^2 are reported for each model (includes fixed and random effects) (Xu, 2003). All code for preparing data and testing statistical models is provided as Rmd and HTML files on the Open Science Framework website [https://osf.io/8fqcx/#] (also see Appendix A).

Results

Traditional and Gaze-cueing Antisaccade Tasks AST difficulty was assessed using participant's accuracy rates and response time, such that lower accuracy rates and longer response times indicate greater task difficulty (Heitz & Engle, 2007; Shipstead et al., 2015; Theeuwes, 2010). Two linear mixed-effects models with planned contrasts were used to evaluate differences in response times and accuracy rates between the three ASTs. The first model evaluated response times using planned contrasts that allowed comparisons between: (1) the traditional and the static AST, (2) the traditional and the dynamic AST, and (3) the static and dynamic AST relative to their respective performance on the traditional task. The second model compared accuracy rates using the same planned contrasts. All models shared an initial random effects structure, with intercepts for participants that included random intercepts and slopes for delay (the time between the fixation screen and attractor onset). If models did not converge, we simplified them by removing terms from the random effect structure, starting with the higher order terms (see the recommendations of Bates, Kliegl, Vasishth, & Baayen, 2015), until the most complex model that converged was obtained. Table 1 shows overall descriptives for performance on the gaze-following (static and dynamic) and traditional AST. Table 2 provides a summary of model results.

Table 1

Antisaccade Tasks Descriptive Statistics

Static Group				
Type	*Mean ACC (%)*	*SE*	*Mean RT (ms)*	*SE*
Traditional	59.27	0.82	756.15	6.14
Gaze-following	87.67	0.55	661.83	5.50
Dynamic Group				
Traditional	59.73	0.81	734.49	6.13
Gaze-following	75.57	0.70	727.46	5.95

Note. ACC = Accuracy rate (%); RT = Response time in milliseconds

Response time model. A likelihood ratio tests was performed between the fully-specified model and a model that included only random effects, the response time model was statistically significant (χ^2 (2,10) = 157.92, p < .001, R^2 = 0.24). For the tests involving planned contrasts, participants displayed faster response times on the static AST than the traditional AST (β = -0.05, SE=0.004, p <.001), but there was no difference in response times between the dynamic and traditional AST. Furthermore, participants in the static gaze-following group displayed faster response times than participants in the dynamic gaze-following group (β = 0.06, SE = 0.006, p <.001).

Table 2

Antisaccade Mixed Effects Models Results

Response Time	*β*	*SE*	*t*	*p*
Static x Traditional	-0.05	0.004	-12.60	< .001
Dynamic x Traditional	0.001	0.004	0.28	0.78
Dynamic x Static	0.06	0.006	9.15	< .001
Accuracy	B	*SE*	*t*	*p*
Static x Traditional	1.69	0.06	26.86	< .001
Dynamic x Traditional	0.82	0.05	15.26	< .001
Dynamic x Static	-0.86	0.08	-10.46	< .001

Note. Response times values represent log 10 transformed data

Accuracy rate model. Based on a loglikelihood ratio test, the overall accuracy model was significantly different from the null model with only random effects (χ^2 (2,9) = 1063.9, p < .001). R^2 was not calculated for the overall accuracy model as the Xu (2003) method is not compatible with binomial variables and no sufficient alternative formula was found. Accuracy rates were higher in the static AST than the traditional AST (B = 1.69, SE = 0.06, p <.001), and higher in the dynamic AST than the traditional task (B = 0.82, SE =

0.05, *p* <.001). Finally, the accuracy rates were higher on the static AST as than the dynamic AST (B = -0.84, SE = 0.08, *p* <.001).

Working Memory and Gaze-cueing Antisaccade Tasks A composite working memory score (WM Span) was created by averaging the participants' normalized scores on the Ospan (M = 34.51, SE = 0.06) and Sspan (M = 17.21, SE = 0.03) tasks. A linear mixed-effects models with planned contrasts were used to evaluate differences in response times and accuracy rates between the three ASTs. The first model evaluated response times using planned contrasts that allowed comparisons between: (1) the traditional and the static AST, (2) the traditional and the dynamic AST, and (3) the static and dynamic AST relative to their respective performance on the traditional task. WM Span did not predict response times on the static AST; however it was a significant predictor of response times on the dynamic AST (*B* = -63.12, *SE* = 26.02, *t*(63) =-2.43, *p* = 0.02), such that higher working memory scores were associated with faster response times (see Figure 6).

A simple linear regression model were calculated to predict gaze-cueing AST accuracy rates based on WM Span. WM Span failed to predict performance on the static AST. However, WM Span was a significant predictor of accuracy rates on the dynamic AST (*B* = 0.06, *SE* = 0.03, *t*(59) =3.14, *p* =0.002), such that higher working memory scores were associated with greater accuracy ($F(1,61) = 9.88$, $p = .003$, , $R^2 = 0.14$) (see Figure 6).

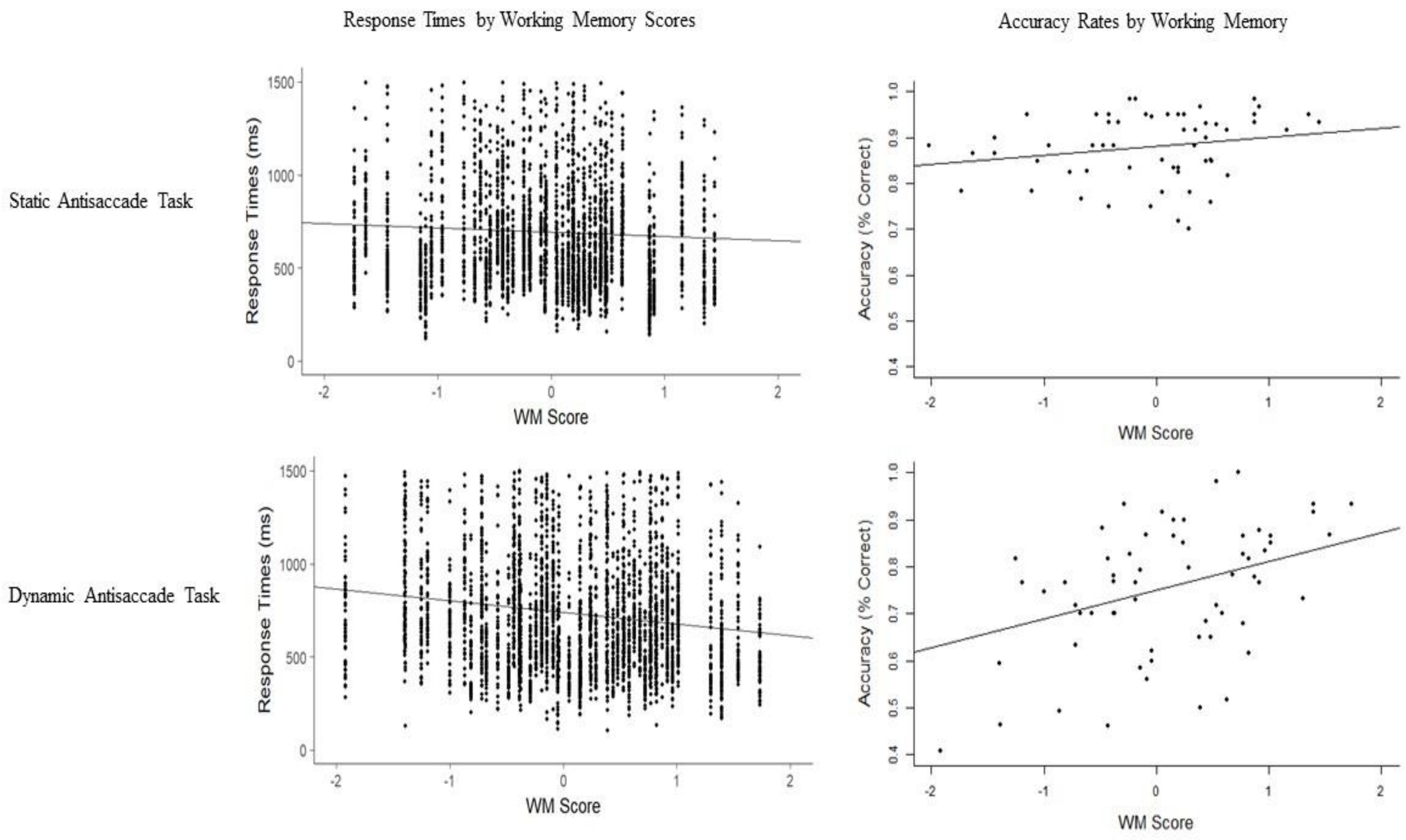


Figure 6: Working Memory Scores and Gaze-following Antisaccade Performance

DISCUSSION

It has been well established that gaze cues elicit reflexive bottom-up orienting; but, unlike traditional stimuli (e.g., arrow cues), orienting occurs even when gaze cues are centrally presented and counterpredictive of a target's location (Friesen & Kingstone, 1998; Friesen et al., 2004a). Thus, it was hypothesized that the gaze-following ASTs would be more difficult to perform than the traditional task. Lower accuracy rates and slower response times were expected on the gaze-following AST than the traditional AST, with performance being the lowest in the dynamic gaze-following AST. The obtained results were unanticipated and provide interesting insight into the complex nature of gaze stimuli.

Contrary to our expectations, participants displayed faster response times and higher accuracy rates in the static gaze-following AST than the traditional AST. Additionally, working memory was unrelated to static AST performance. These results suggest that the static gaze stimuli used in this study likely elicited minimal bottom-up demands on attention control. On the other hand, the dynamic AST was more aligned with our original predictions. Although accuracy rates were higher in the dynamic AST task than the traditional task, there was no difference in response time compared to the traditional AST. Furthermore, working memory span was related to the dynamic AST such that individuals with higher working memory spans responded faster and more accurately than those with lower spans.

One interpretation of our results is that static, and to some extent dynamic, gaze-cues of a real face do not tap into attentional capacities as strongly as traditional peripheral stimuli. This is likely because gaze-cues do not elicit bottom-up orienting as strongly as peripheral cues. However, when limiting our evaluation of performance to just gaze-cue types, the difference between static and dynamic AST performance does reveal that increasing the complexity of gaze stimuli (from static to dynamic) requires greater top-down control to override bottom-up facilitation.

The working memory results also provide some additional insight into the utility of gaze-cueing for measuring attention control. Given individual differences in working memory ability have been shown to be highly related to attention control performance (Unsworth et al., 2004), it is not too surprising that there was no relationship with the static eye-gaze stimuli for this study. But as the stimuli being processed increases attentional demands, as with the dynamic gaze cues, we would expect working memory ability to predict performance. Indeed, this was the case. Overall the results of this study suggest that static and dynamic gaze cues of a real person's face are not sufficient substitutes for traditionally used peripheral flash stimuli. It does, however, appear as though more complex gaze cues (and perhaps other social cues) might provide the bottom-up strength required to develop more "real-world" measures of attention control.

One possible alternative explanation for the obtained results is that repeated exposure to the gaze cues served as a cue of where *not* to look on. Research on basic visual attention has found that repeated exposure to a distractor can lead to the development exclusionary attentional templates. Over time these distractors actually facilitate visual search performance by limiting the area of search for the target.

Beck, Luck, and Hollingworth (2017) demonstrated that people can use previously provided information about a distractor to aide visual search. They found that to-be-avoided objects (cued prior to the start of a trial) reliably captured attention in early trials; however, these distractors were later avoided (i.e., there were fewer saccades made to the distractors over the course of the trial). Additionally, Vatterott, Mozer, and Vecera (2018) found that over a sequence of singleton search trials, people learn to ignore salient distractors. Most interestingly, they were able to generalize this learning to new distractors. 2003). Together, these results suggest that repeated exposure to a distractor can actually aide a person's ability to control attention in two ways: (1) by reducing the bottom-up strength of the stimuli through repeated punishment (i.e., failing the trial) and (2) reducing the area of the visual search. Furthermore, research on individual differences in working memory ability has shown that repeated exposure to a distracting stimulus facilitates working memory goal maintenance in individuals with low working memory abilities (Kane & Engle, 2003). Critically, this leads to fewer errors in attention control tasks, likely due to the frequent reinforcement of the individual's goal by the environment (i.e., the eyes will look in the wrong way, don't look that way).

It is highly possible, especially if gaze cues were not a strong bottom-up distractor, that performance on the gaze following ASTs varied over time, with performance improving over the course of the trial. Furthermore, this improvement is likely different for the two gaze-following AST types with the performance increasing most rapidly in the static AST. Future research should investigate if this is the case. The discovery of a learned gaze avoidance would provide valuable insight into the way human's use gaze cues in the real world.

Limitations and Future Directions

One limitation of this study was the lack of a motion control stimulus that was equivalent to the dynamic stimuli (i.e., a non-social stimulus which moved). It is possible that the dynamic antisaccade task performed more similar to the traditional task simply because of the differences in the time it tasks to process still and moving centrally presented stimuli. Motion, not gaze, may have been the true bottom-up distractor in the task. Future research should evaluate if dynamic non-social stimuli captures attention to a similar degree as our dynamic gaze stimuli.

Similar to the conclusions of Risko et al. (2012), these results demonstrate the need to systematically compare social stimuli that range in their approximation to real human interaction. I also strongly argue that it is critical to evaluate social stimuli within the framework of traditional theories and models of cognition (e.g., working memory). Although basic gaze stimuli are thought to have a similar influence as stimuli used in traditional peripheral attention control task, when systematically compared to traditional tasks, this assumption might need further evaluation.

REFERENCES

Bates, D., Maechler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67*(1), 1-48.

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious Mixed Models. *preprint arXiv:* 1506.04967v1

Beck, V. M., Luck, S. J., Hollingworth, A. (2017). Whatever You Do, Don't Look at the. .: Evaluating Guidance by an Exclusionary Attentional Template. *Journal of Experimental Psychology: Human Perception and Performance*.

Connor, C. E., Egeth, H. E., & Yantis, S. (2004). Visual attention: Bottom-up versus top-down. *Current Biology, 14*(19), 850-852.

Conway, A. R., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences, 7*(12), 547-552.

Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, Z. D., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12*(5), 769-786.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., Baron-Cohen, S. (1999). Gaze Perception triggers reflexive visuospatial orienting. *Visual Cognition, 6*(5), 509-540.

Engle, R. W., (2002). Working Memory Capacity as Executive Attention. *Current Directions in Psychological Science, 11*(1), 19-23.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze Cueing of Attention: Visual Attention, Social Cognition, and Individual Differences. *Psychological Bulletin, 133*(4), 694-724.

Friesen, C.K. & Kingstone, A., (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5*(3),490–495.

Friesen, C. K., Ristic, J., & Kingstone, A. (2004a). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology Human Perception and Performance, 30*(2), 319-329.

Frischen, A., Tipper, S., & Lindsay, D. Stephen. (2004b). Orienting Attention Via Observed Gaze Shift Evokes Longer Term Inhibitory Effects: Implications for Social Interactions, Attention, and Memory. *Journal of Experimental Psychology: General, 133*(4), 516-533.

Heitz, R. P., & Engle, R. W. (2007). Focusing the spotlight: Individual differences in visual attention control. *Journal of Experimental Psychology: General, 136*(2), 217-240.

Hutton, S. B. (2008). Cognitive control of saccadic eye movements. *Brain and Cognition, 68(*3), 327-340

Hutton, S., & Ettinger, U. (2006). The antisaccade task as a research tool in psychopathology: A critical review. *Psychophysiology, 43*(3), 302-313.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*(2), 169-183.

Kane, M., & Engle, R. (2003). Working-Memory Capacity and the Control of Attention: The Contributions of Goal Neglect, Response Competition, and Task Set to Stroop Interference. *Journal of Experimental Psychology: General, 132*(1), 47-70.

Kingstone, A., Laidlaw, K. E., Nasiopoulos, E., & Risko, E. F. (2016). Cognitive ethology and social attention. In M. Tibayrenc, & J. Francisco, *On Human Nature* (1 ed.). Elsevier Inc.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R.H.B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software, 82*(13), pp. 1-26.

Langton, S. R. H., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? cues to the direction of social attention. *Trends in Cognitive Sciences, 4*(2), 50-58.

Marino, B. F. M., Mirabella, G., Actis-Grosso, R., Emanuela, B., Ricciardelli, P. (2015). Can we resist another person's gaze? *Frontiers in Behavioral Neuroscience, 9*.

Morey, C. C., Elliott, E. M., Wiggers, J., Eaves, S. D., Shelton, J. T., & Mall., J. T. (2012). Goal-neglect links Stroop interference with working memory capacity. *Acta Psychologica, 141*(2), 250-260.

Mulckhuyse, M. & Theeuwes, J. (2010). Unconscious attentional orienting to exogenous cues: A review of the literature. *Acta Psychologica, 134*(3), 299-309.

Mundy, P. & Jarrold, W. (2010). Infant joint attention, neural networks and social cognition. *Neural Networks, 23*(8), 985-997.

Mundy, P., & Newell, L. (2007). Attention, Joint Attention, and Social Cognition. *Current Directions in Psychological Science, 16*(5), 269-274.

Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. *Trends in Cognitive Sciences, 13*(3), 135-143.

Posner, M., & Rothbart, M. (2007). Research on Attention Networks as a Model for the Integration of Psychological Science. *Annual Review of Psychology, 58,* 1-23.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
URL: http://www.R-project.org/

Ricciardelli, P. M., Bricolo, E., Aglioti, S., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *NeuroReport*, *13*(17), 2259-2264.

Risko, E. F., Laidlaw, K. E., Freeth, M., Foulsham, T., & Kingstone, A. (2012). Social attention with real versus reel stimuli: towards an empirical approach to concerns about ecological validity. *Frontiers in Human Neuroscience, 6.*

Roberts, R. J., Hager, L. D., & Heron, C. (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology; General, 123*(4), 374.

Shipstead, Z., Harrison, T. L., & Engle, R. W. (2015). Working memory capacity and the scope and control of attention. *Attention, Perception, & Psychophysics, 77*(6), 1863-1880.

Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica, 135*(2), 77-99.

Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: Individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(6), 1302-1321.

Van Zoest, W., & Donk, M. (2004). Bottom-up and Top-down Control in Visual Search. *Perception, 33*(8), 927-937.

Vatterott, D., Mozer, B., & Vecera, M. (2018). Rejecting salient distractors: Generalization from experience. *Attention, Perception, & Psychophysics, 80*(2), 485-499.

Wolohan, F., & Crawford, D. (2012). The anti-orienting phenomenon revisited: Effects of gaze cues on antisaccade performance. *Experimental Brain Research, 221*(4),385-3.

Xu, R. (2003). Measuring explained variation in linear mixed effects models. *Statistics in Medicine, 22*(22), 3527-3541.

APPENDIX A

CODE FOR DATA PREPARATION AND STATISTICAL MODELS

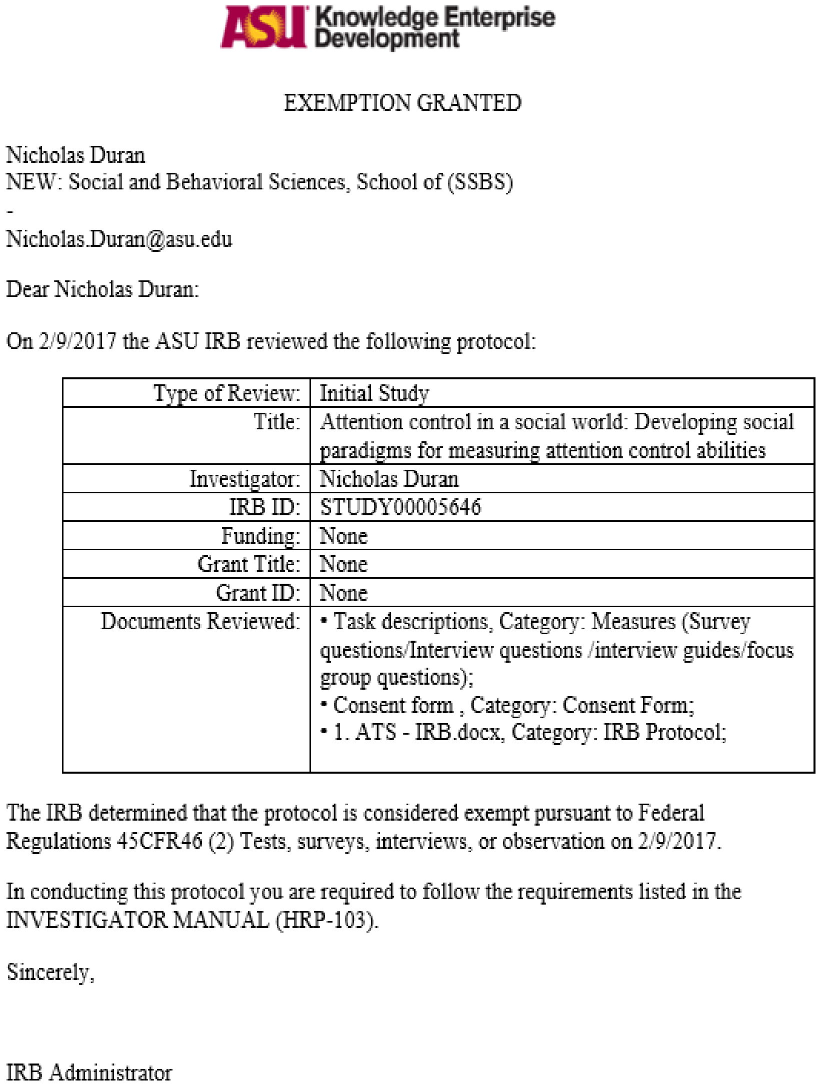
Files provided in Rmd and HTML formats and require R Studio or internet access to view.

All code and statistical output are available on the Open Science Framework website as Rmd and html files. They require either R software or internet access to view.

LINK: https://osf.io/8fqcx/#

APPENDIX B

IRB APPROVAL DOCUMENTS



ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Nicholas Duran
NEW: Social and Behavioral Sciences, School of (SSBS)
-
Nicholas.Duran@asu.edu

Dear Nicholas Duran:

On 2/9/2017 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Attention control in a social world: Developing social paradigms for measuring attention control abilities
Investigator:	Nicholas Duran
IRB ID:	STUDY00005646
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Task descriptions, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Consent form , Category: Consent Form; • 1. ATS - IRB.docx, Category: IRB Protocol;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 2/9/2017.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator