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To what extent is the contribution of language to learning via instructions modulated by the expression of autism traits?

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Abstract

Language plays a fundamental role in enabling flexible, goal-directed behaviour. This study investigated whether the contribution of language to instruction encoding is modulated by the expression of autism traits, as measured by the Autism Spectrum Quotient (ASQ) questionnaire. Participants (N=108) completed six choice reaction time tasks, with each task consisting of six stimulus-response mappings. During an instruction phase preceding each task, participants performed either a verbal, non-verbal or no distractor task. Participants made more errors in the verbal distractor task condition, but this detrimental effect did not differ significantly between the high (top 33%) and low (bottom 33%) ASQ groups. Hence, the contribution of language to instruction encoding does not appear to be modulated by the expression of autism traits.

Key words: Language, learning, inner speech, autism.

Language plays a crucial role in guiding our behaviour in a flexible and goal directed manner. Studies with neurotypical adults and children have demonstrated that performance in a range of cognitive domains including planning (Lidstone, Meins & Fernyhough, 2010), working memory (Ang & Lee, 2008) and task switching (e.g., Baddeley, Chincotta & Adlam, 2001; Saeki & Saito, 2009; Miyake, Emerson, Padilla & Ahn, 2004) is impaired when the use of inner speech is disrupted. Such studies clearly demonstrate that in neurotypical individuals, language makes a key contribution to the flexible control of behaviour.

In contrast, there are theoretical reasons to believe that inner speech may be impaired in autism (Fernyhough, 2008; Williams, Peng & Wallace, 2016). Autism is characterised by social-communication issues and difficulties in behavioural and cognitive flexibility. From a Vygotskian perspective, social-communication difficulties could cause impaired inner speech, which in turn may result in behavioural and cognitive inflexibility (Williams et al., 2016). Consistent with this, a number of studies have found evidence for atypical inner speech in autism. For example, Williams, Bowler and Jarrold (2012) found that articulatory suppression affects planning on a Tower of London task in neurotypical adults, but not in autistic individuals. Similarly, a number of studies have found that the ability to switch between tasks is mediated by language in neurotypical children, but not in autistic children (Whitehouse, Mayberry & Durkin, 2006; Holland & Low, 2009). However, other studies have found no evidence of an inner speech impairment in autism (Williams, Happé & Jarrold, 2008; Winsler, Abar, Feder, Schunn & Rubio, 2007). Additionally, Williams et al. (2016) have questioned the quality of the evidence in support of an inner speech impairment in autism, citing methodological issues (such as the lack of an appropriate control conditions, and small sample sizes) as a barrier to determining whether inner speech is atypical in autism, or not.

In addition to the methodological issues highlighted by Williams et al. (2006), there is another possible explanation for the seemingly inconsistent results with regards to the status of inner speech in autism. Specifically, recent studies with neurotypical adults have shown that the contribution of language to the flexible control of behaviour is not uniform. Rather, these studies have shown that task performance is mediated verbally only when that task is novel, and not when it is well-practiced, consistent with theories of skill acquisition and instruction following (e.g., Anderson, 1982; Brass, Liefooghe, Brahm & De Houwer, 2017). For example, Van ‘t Wout and Jarrold (2020) required participants to learn novel sets of unfamiliar stimulus-response (S-R) mappings whilst performing a verbal distractor task (articulatory suppression; AS) or a non-verbal distractor task (foot tapping; FT). Participants made more errors under AS, but only when the task was new, and not when it was well-practiced (also see Monsell & Graham, 2021). In a subsequent study, Van ‘t Wout and Jarrold (2022) investigated whether language plays a role in encoding task instructions prior to task performance. Participants were required to learn sets of six arbitrary stimulus-response mappings via instruction. During the instruction phase, which consisted of a visual representation of the correct S-R mappings, participants were required to perform AS, FT or no distractor task. Participants made more errors on the task if AS had been performed during the instruction phase, suggesting that language plays a crucial role in encoding unfamiliar task instructions in neurotypical adults. However, it remains unknown to what extent the contribution of language to instruction encoding is modulated by the expression of autism traits.

To investigate this possibility, the current, preregistered, study required participants to learn a series of novel tasks (with each task consisting of six arbitrary S-R rules) via instruction, using a procedure identical to that used by Van ‘t Wout and Jarrold (2022; Experiment 2). Specifically, prior to performing each task, participants were shown an instruction screen displaying the correct S-R mappings for that task. During this instruction phase, which was either long (60 seconds) or short (10 seconds), participants were required to perform either a verbal distractor task (AS), a non-verbal distractor task (FT), or no distractor task. To investigate whether the contribution of language to instruction encoding is modulated by the expression of autism traits, participants also completed the Autism Spectrum Quotient questionnaire (ASQ; Baron-Cohen, Wheelwright, Skinner & Martin, 2001). Autism is a spectrum condition, and expression of autism traits can be reliably measured in subclinical populations (Ruzich et al., 2015). In this way, the current study sought to investigate whether the role of language in instruction encoding is modulated by the expression of autism traits.

Specifically, our primary prediction was that participants with high ASQ scores (top 33%) would show a smaller detrimental effect of AS on accuracy compared to participants with low ASQ scores (bottom 33%), if participants with high ASQ scores are less likely to employ a linguistic strategy when encoding novel task instructions. With regards to the effect of instruction duration, we predicted three possible outcomes: 1) Participants in the low ASQ group might be worse in the AS condition especially when the instruction duration is short. This might be expected if the high ASQ group exhibit superior non-verbal strategies, in which case they might benefit from such strategies more under time pressure; 2) One could also predict that participants with high ASQ scores might benefit more from the use of superior non-verbal strategies with a longer instruction duration, resulting in better performance under AS in the 60 second instruction duration condition in that group compared to the low ASQ group; 3) Finally, one might expect participants in the low ASQ group to outperform participants under FT in the long instruction duration condition, when participants with low ASQ scores are likely to benefit from the use of verbal strategies.

Method

Participants

As specified in our preregistered plan (http://dx.doi.org/10.23668/psycharchives.4708), the total number of participants that took part in this study was 108 (aged between 18 and 41 [mean age = 20], 86 female/21 male (1 "prefer not to say")). This number was based on a power calculation performed on existing data from a previous similar study[1] (Van 't Wout & Jarrold, 2022). All participants provided informed consent prior to taking part, and the experiment was approved by the University of Exeter's Psychology Ethics Committee (ID eCLESPsy002342). All participants were paid £4 or received course credit in return for their participation.

[1] Van 't Wout and Jarrold (2022) found an effect size of .637 for the difference between the AS and FT conditions. G-Power estimated that 34 participants would be needed to detect this effect size at 95% power with an alpha of 5% within each ASQ group. We increased this number to 36 participants per group in order to accommodate between-subject counterbalancing of distractor task order and response assignment.

Design

The experiment was programmed in PsychoPy (Peirce et al., 2019). All participants completed the experiment online via Pavlovia. The experimental task used was identical to the task used by Van ‘t Wout and Jarrold (2022, Experiment 2). Each participant completed six identically structured choice reaction time tasks. For each task, participants were required to respond to one of six picture stimuli using one of six key board response keys (x, c, v, b, n and m). Different pictures were used in each task, so that each task required the acquisition of six unfamiliar and arbitrary S-R rules. Six sets of six pictures each were selected from the International Picture Naming Project (IPNP; Bates et al., 2003; see Table 1).

[Insert Table 1 here]

Each stimulus occurred six times within a task (a total of 36 trials per task), and the trial sequence was pseudorandomised so that immediate stimulus repetitions did not occur. The trial structure was identical across all tasks: Each trial began with a centrally presented fixation cross (250ms), followed by a target stimulus which remained on screen until a response was made. If participants made an error, a 1000ms error message was presented in the centre of the screen (see Figure 1).

[Insert Figure 1 here]

Prior to the start of each task, participants viewed an instruction screen, which displayed (simultaneously) all six stimuli for that task from left to right (i.e. the stimulus in the leftmost position mapped onto the x response key, and the stimulus in the rightmost position mapped onto the m response key; see Figure 2 for an example). During the instruction phase (but not during task performance itself), participants were required to perform either a verbal distractor task (articulatory suppression; AS), a non-verbal distractor task (foot tapping; FT) or no distractor task to the beat of a metronome (100 beats per minute)[2]. Participants performed each distractor task condition twice, once with an instruction duration of 10 seconds and once with an instruction duration of 60 seconds. The order of instruction duration, distractor task condition, the assignment of stimuli to responses and the assignment of stimulus sets to conditions were counterbalanced between participants.

[Insert Figure 2 here]

The experiment was preceded by a practice phase, which consisted of practicing the distractor tasks (AS and FT) for 60 seconds each, and completing a practice task of 36 trials. This practice task was identical to the no distractor task condition (with a 60S instruction duration), and involved stimuli which did not appear in the main experiment. Upon completion of the main experimental task, all participants completed an online version (programmed in PsychoPy) of the Autism Spectrum Questionnaire (ASQ; Baron-Cohen et al., 2001). The ASQ is a 50-item questionnaire which measures the expression of autistic traits, and has been shown to have adequate internal consistency and test-retest reliability (e.g., Baron-Cohen et al., 2001; Hoekstra, Bartels & Boomsma, 2008). All 50 statements from the ASQ were presented one at a time on the computer screen, in a fixed order. Participants were required to rate each statement on a 4-point scale, using the 1, 2, 3 and 4 keys on a computer keyboard to indicate their response (definitely agree, slightly agree, slightly disagree, definitely disagree). Scores can range from 0 to 50, with higher scores indicating a greater expression of autistic traits. Upon completion of the ASQ, participants were thanked and debriefed. In total, the experiment lasted approximately 25 minutes.

[22] Foot tapping (tapping one foot) and articulatory suppression (saying "tick, tick, tick") were chosen as distractor tasks, as previous research has shown that these distractor tasks are well-matched in terms of difficulty (Miyake et al., 2004; Van 't Wout & Jarrold, 2020). Participants also heard the metronome during the instruction phase of the no distractor task condition, but they were instructed to ignore it.

Results

In line with our preregistered analysis plan, data from 12 participants with mean RTs or error rates more than three standard deviations above the grand average were removed and replaced[3]. Additionally, RTs smaller than 200ms or greater than 5000ms (0.6% of correct responses) were excluded from the data set. Prior to conducting the analyses described below, participants were ranked according to their ASQ score and assigned to a high ASQ group (top 33%) or a low ASQ group (bottom 33%). In line with our preregistered plan, participants with intermediate ASQ scores were not included in the analysis. Participants in the low ASQ group had a mean ASQ score of 11 (min=4; max=14), and participants in the high ASQ group had a mean score of 25 (min=19; max=37).

A 2 (instruction duration: 10S or 60S) x 3 (distractor task: AS, FT or None) x 2 (ASQ group: Low or High) mixed ANOVA was run on the % error and mean correct RT data. For the % error data, this analysis revealed a significant main effect of instruction duration, F(1,70)=81.41, p<.001, η_p^2=.538, a significant main effect of distractor task, F(2,140)=35.47, p<.001, η_p^2=.336, and a significant interaction between instruction duration and distractor task, F(2,140)=5.01, p=.012, η_p^2=.067. As can be seen from Figure 3, participants made more errors in the AS condition compared to the FT and no distractor task conditions. This detrimental effect of AS compared to FT was greater with a short instruction duration (AS-FT difference: 13.1±2.5%) than with a long instruction duration (AS-FT difference: 6.3±1.4%), replicating the results of Van 't Wout and Jarrold (2022, Experiment 2).

[Insert Figure 3 here]

Contrary to our predictions, there were no significant effects of or interactions with ASQ group (all F's < 1.76). Although the detrimental effect of AS compared to FT was numerically larger in the Low

[3] The demographic characteristics of the participants excluded from the analysis (75% female, mean ASQ score = 17) were similar to those of the participants included in the analysis (80% female, mean ASQ score = 18).

ASQ group (13.9±4.2% with 10S; and 8.0±2.2% with 60S) than in the High ASQ group (12.2±2.8% with 10S; and 4.5±1.6% with 60S), the interaction between ASQ Group, instruction duration and distractor task was not significant, F(2,140)=1.76, p=.181, η_p^2=.025 (H-F).

For the mean correct RT data, the same 2 (instruction duration: 10S or 60S) x 3 (distractor task: AS, FT or None) x 2 (ASQ group: Low or High) mixed ANOVA produced only a significant main effect of distractor task, F(2,140)=8.87, p<.001, η_p^2=.113. None of the other main effects or interactions were significant (all F's < 1.54). Three further one-way ANOVAs comparing the distractor task conditions against one another (averaged across instruction duration) found that RTs were significantly faster in the AS condition (1057±25ms) compared to the FT condition (1123±27ms), F(1,71)=13.59, p<.001, η_p^2=.161; and significantly faster in the AS condition compared to the no distractor task condition (1117±28ms), F(1,71)=11.85, p<.001, η_p^2=.143. The difference between the FT and no distractor task condition was not significant, F(1,71)=.12, p=.733, η_p^2=.002.[4]

Discussion

This study sought to investigate whether participants with high scores on the Autism Spectrum Quotient (ASQ) are less likely to use language when learning novel tasks via instruction than participants with low ASQ scores. Consistent with Van 't Wout and Jarrold (2022), the results showed that participants made more errors on a choice reaction time task when articulatory suppression (AS) had been performed during the instruction phase compared to foot tapping (FT), especially when the instruction phase was short (10 seconds) rather than long (60 seconds). However, this detrimental effect of AS was not significantly different for participants with high and low ASQ scores.

[4] Previous studies have also found that reaction times are sometimes faster under AS than under FT (e., Bryck & Mayr, 2015; Van 't Wout & Jarrold, 2022). Additionally, Van 't Wout and Jarrold (2022) demonstrated that the increase in errors under AS (compared to FT) cannot be attributed exclusively to faster RTs in that condition.

These results suggest that the contribution of language to instruction encoding is not modulated by the expression of autism traits. One possible explanation for this finding is that this study did not include a wide enough range of ASQ scores. This seems unlikely, given that the scores in the high and low ASQ groups in the current study (low ASQ group: 4-14; high ASQ group: 19-37) were comparable to those in previous studies, in which participants in the low ASQ group had scores in the 0-15 range, and participants in the high ASQ group had scores in the 16-30 range (Bayliss & Kritikos, 2011; Ferraro, Hansen & Deling, 2016; Lindell, Notice & Withers, 2009). Contrary to the current study, these previous studies did find that participants in low and high ASQ groups differed significantly in terms of their performance on a range of cognitive tasks, including tasks measuring executive functioning (Ferraro et al., 2016), selective attention (Bayliss & Kritikos, 2011) and language processing (Lindell et al., 2009). Given this, it seems unlikely that the current study did not employ a sufficiently wide range of ASQ scores.

The most obvious explanation for the current findings, then, is that the role of language in instruction encoding is not modulated by the expression of autism traits. Previous studies investigating inner speech impairments in autism have yielded conflicting results, with some studies finding evidence for atypical use of inner speech in autism, whereas others did not. Furthermore, as noted by Williams et al. (2016), many of the studies showing an impairment of inner speech in autism suffered from methodological limitations, including small sample sizes and a lack of appropriate control conditions. The current study addressed such methodological concerns by employing a large sample size based on a-priori power calculations, and it also included an appropriate non-verbal control condition (foot tapping). In spite of this, the current study obtained no support for the assertion that inner speech is modulated by the expression of autism traits, thus adding further evidence against the idea that autism is characterised by broad atypicalities in inner speech.

In addition to the methodological limitations of previous studies, there are three other explanations for the inconsistent findings with regards to inner speech in autism. First, as a spectrum condition, autism is a highly heterogeneous disorder, and therefore it is possible that whereas some autistic individuals exhibit atypical inner speech, others may not. For example, Lidstone, Fernyhough, Meins and Whitehouse (2009; also see Williams & Jarrold, 2010) previously showed that an inner speech impairment in autistic children was only present in a subgroup of children who exhibited greater nonverbal than verbal ability. This finding (atypical inner speech only for autistic children with reduced verbal ability scores) might explain why previous studies have found conflicting results with regards to whether or not inner speech is affected in autistic individuals (see Lidstone et al. 2009). Although the current study did not measure verbal ability scores, it is possible that verbal ability scores did not differ between the high and low ASQ groups, resulting in a comparable detrimental effect of AS in both groups.

Second, it is possible that only some but not other forms of inner speech are atypical in autism. Specifically, it has previously been argued that only dialogic inner speech (which requires the consideration and coordination of different perspectives) but not monologic inner speech (which involves the repetitive rehearsal of verbal material) is impaired in autism (Alderson-Day & Fernyhough, 2015; Williams et al., 2008). The paradigm employed in the current study likely recruited monologic rather than dialogic inner speech, which could potentially explain why the low and high ASQ groups were not differentially affected by articulatory suppression.

Finally, one other factor which may have influenced the results of the current study is that 80% of the participant sample was female. In contrast, the male-to-female ratio in autism is thought to be 3:1 (Loomes et al., 2017). The discrepancy between the proportion of women in our participant sample on the one hand, and the proportion of women among individuals with an autism diagnosis on the other hand, may constrain the generalisability of our results. However, given that we still obtained a sufficiently wide range of ASQ scores (as noted above), it seems unlikely that the high proportion of female participants is the cause of the key finding of no interaction between ASQ group and the detrimental effect of articulatory suppression on performance.

In sum, the current study found that the role of language in instruction encoding was not modulated by the expression of autism traits. These findings therefore argue against universally atypical inner speech in autism. It remains unknown whether inner speech is uniformly unaffected by the expression of autism traits, or whether inner speech atypicalities are restricted to certain subsets of autistic individuals (e.g., Lidstone et al., 2009), or specific types of inner speech (e.g., Williams et al., 2008). Future research must systematically investigate such mediating variables in order to gain a comprehensive understanding of the profile of inner speech in autism.

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Table and figures

#	Set 1	RT	%	#	Set 2	RT	%	#	Set 3	RT	%
1	egg	874	98	7	spoon	777	100	13	bus	771	100
2	car	751	100	8	tent	744	100	14	leaf	848	100
3	tree	796	100	9	box	753	100	15	pen	753	100
4	fan	865	98	10	pig	855	100	16	house	745	98
5	sock	712	100	11	ear	681	100	17	dog	702	100
6	hat	684	98	12	watch	780	100	18	cake	789	100
	Mean	**780**	**99**		**Mean**	**765**	**100**		**Mean**	**768**	**100**

#	Set 4	RT	%	#	Set 5	RT	%	#	Set 6	RT	%
19	heart	720	100	25	frog	751	100	31	bed	706	100
20	owl	837	98	26	chair	732	100	32	fish	777	100
21	foot	758	98	27	hand	723	98	33	cheese	843	100
22	moon	804	100	28	train	838	100	34	clock	772	98
23	key	738	100	29	snake	775	100	35	dress	840	100
24	bread	773	98	30	kite	796	100	36	eye	700	98
	Mean	**771**	**99**		**Mean**	**769**	**100**		**Mean**	**773**	**99**

Table 1. The stimulus sets were identical to those used by Van ‘t Wout and Jarrold (2022). Across sets, stimuli were matched for percent name agreement (%) and average naming latency (ms; norms obtained from the IPNP). Within sets, images were selected as to avoid phonological, semantic or visual similarity.

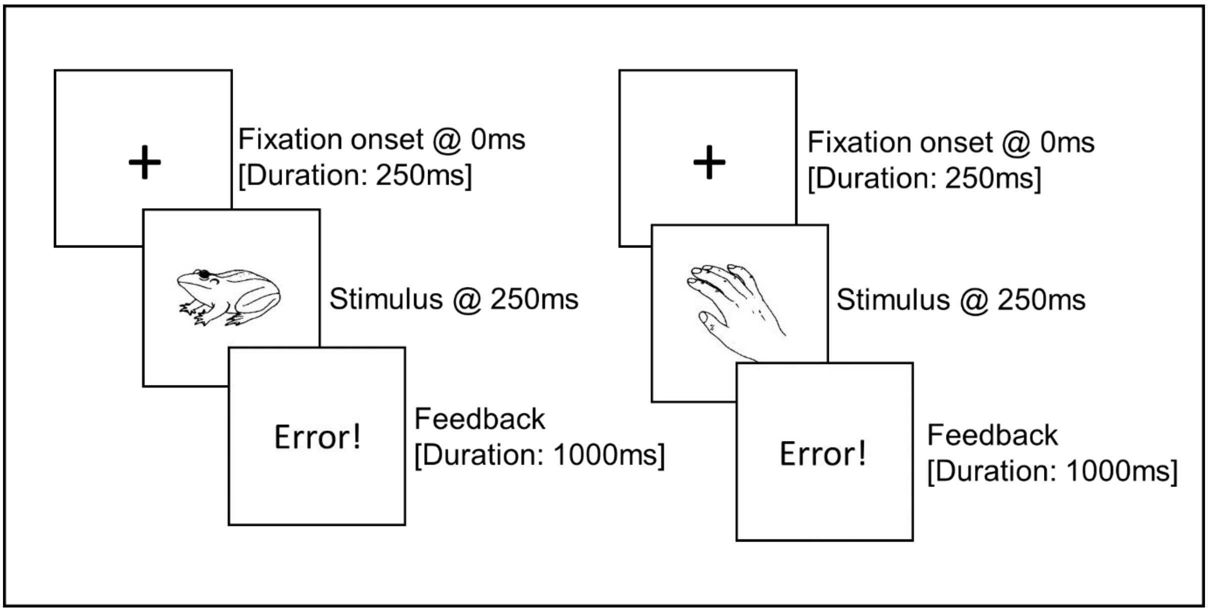

Figure 1. Example of a sequence of two consecutive trials.

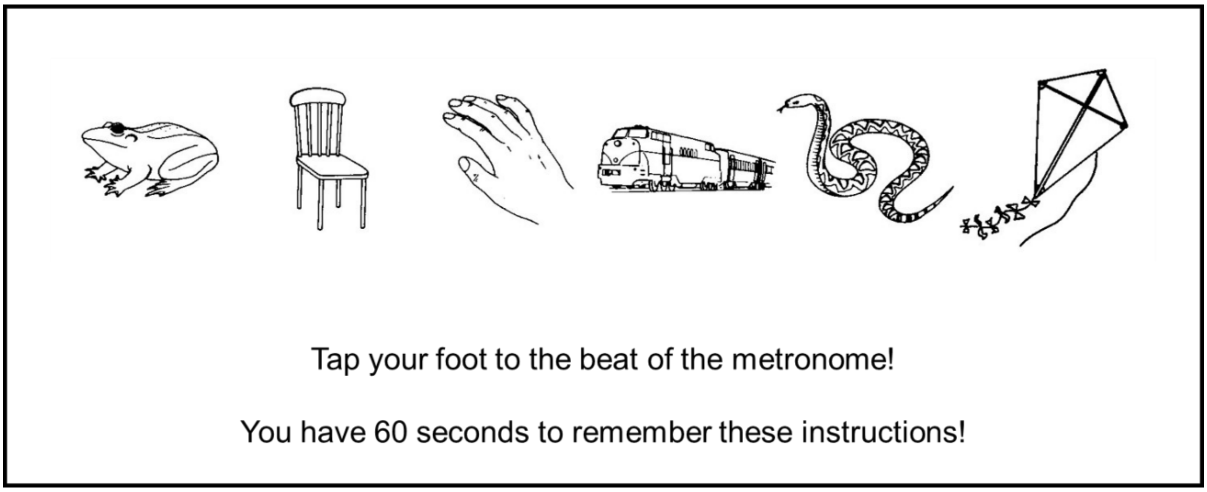

Figure 2. Example of an instruction screen displayed to participants (in the FT condition; instruction duration 60 seconds) prior to the start of a task.

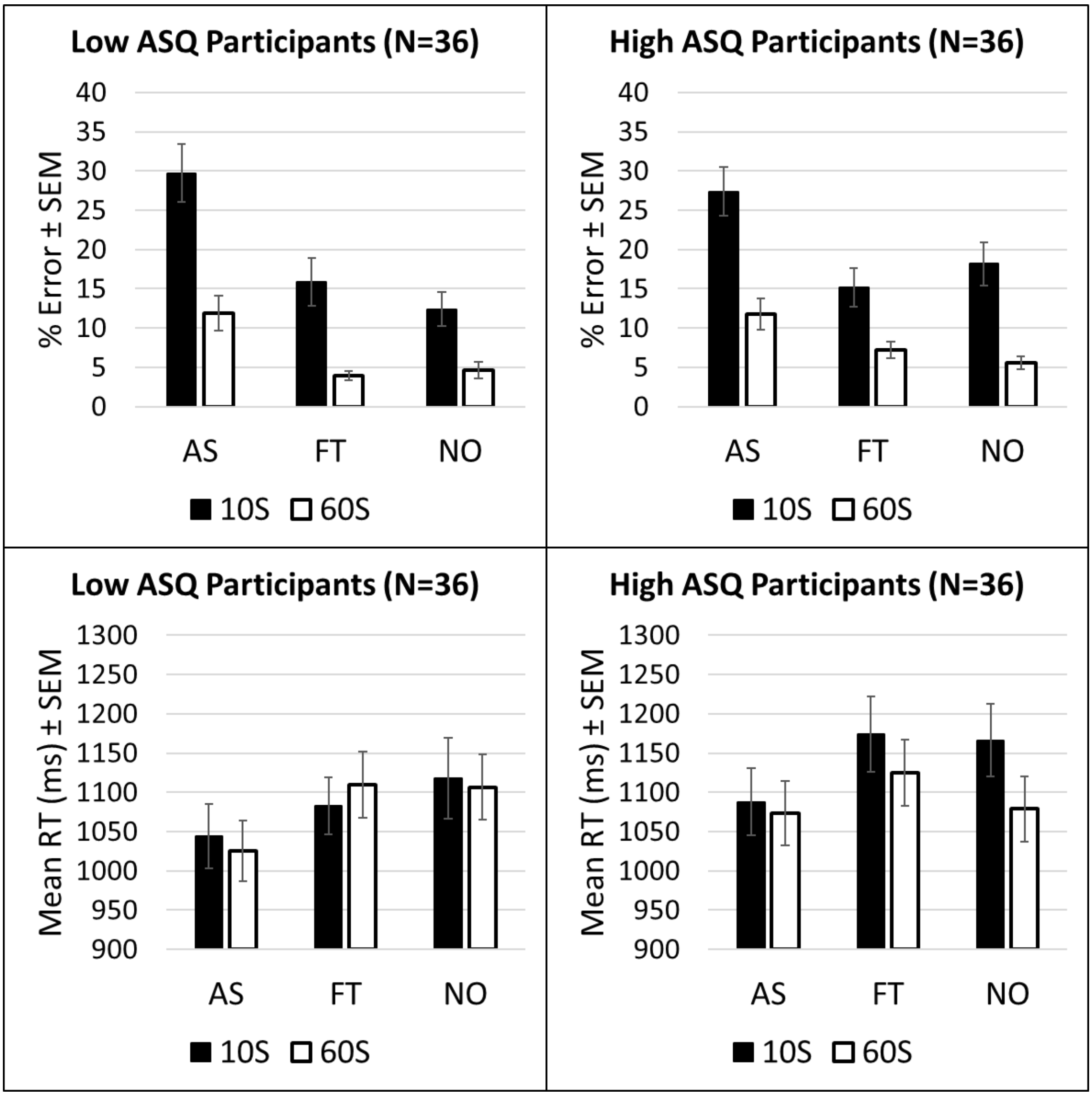

Figure 3. % Error data (top) and mean correct RT data (bottom) for low ASQ participants (left) and high ASQ participants (right), plotted as a function of distractor task condition (AS, FT or none) and instruction screen duration (10 or 60 seconds).