Using Eye Gaze to Examine Language Production Processes in Children with Language Impairments

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Eye Gaze and Language Production Processes

Abstract: Specific Language Impairment (SLI) is a label given to children who have a language impairment not accompanied by hearing loss, cognitive impairment or neurological damage (Leonard, 2014). There is substantial evidence that information processing skills, such as speed of processing or working memory, pose a significant challenge to children with SLI. The extent of these challenges, however, is not yet fully understood. There is some evidence that individuals with SLI experience greater interference from recent information during language processing, possibly due to slow decay of information that is no longer needed. The evidence to date, however, is limited and scattered across varied methods. The examination of eye gaze patterns during language processing has the potential to provide novel insights into online cognitive processing and language planning as it is in progress. This project reports on pilot data examining eye gaze patterns of children with SLI during a picture naming task. Its aim was to develop a better understanding of the nature of processing challenges during language planning and production. Participants with SLI (*n* = 5) and typical language development (*n* = 3) named pictures presented in sets of three on a computer screen and their eye movement patterns were tracked using an SR Research EyeLink 1000 Plus remote eye tracker. Recordings of each child's verbal response and information on timing and accuracy was collected. Our results revealed a similar gaze pattern for both groups but the children with SLI spent more time looking at each individual picture before naming it.

INTRODUCTION

The term specific language impairment (SLI) is commonly used to describe individuals with a language impairment that is not accompanied by deficits in hearing, intelligence, or caused by neurological damage (Leonard, 2014). It is widely acknowledged that information processing challenges are an important part of the profile in SLI. However, the full range of processing challenges is not yet understood. Moreover, how these challenges manifest in language use is not well understood. A body of literature, for example, shows challenges with speed of processing and working memory (Leonard, 2014). In addition, recent studies (Seiger-Gardner & Schwartz, 2007; Poll *et al.*, 2014; McMurray, Samelson, Lee & Tomblin, 2010) point to potential challenges managing interference from recently-processed material that is no longer needed.

In recent years, the research literature has examined the possibility that individuals with SLI exhibit either exceptionally slow or fast decay of information during language and cognitive processing tasks. Slow decay of information is thought to cause inefficient deactivation of previously activated lexical items causing interference with the processing of new information, whereas abnormally fast decay of information may cause an interruption in processing, causing slow processing of language (Seiger-Gardner & Schwartz, 2007). It is thought that the decay rate controls how rapidly activation decreases over time for each lexical unit during word and sentence processing. A sufficiently fast decay rate ensures the activation of a lexical item, once retrieved, quickly returns to its resting level, allowing the activation and retrieval of other lexical items to proceed without interference.

Evidence suggestive of slow decay is provided by a picture-word interference study conducted by Seiger-Gardner and Schwartz (2007). In this study, children with SLI and children with typical language development (TLD) were provided with semantically or phonologically related and unrelated interfering words during the completion of a picture naming task. The interfering words were presented before, during, or after the target pictures to determine the timing of the availability of semantic and phonological information during word planning and production. Semantically related words included words from a superordinate category such as plane/bike, whereas phonologically related words shared the same onset such as cat/car. When semantically related or phonologically related words were presented before the presentation of the target word both groups of children demonstrated semantic and phonological interference effects. That is, both groups had difficulty suppressing the interfering information and naming the word for the picture presented. When the distractors were presented at the same time as the target words both groups of children demonstrated a semantic inhibition effect but a phonological inhibition effect was no longer seen. A difference between the two groups was seen, however, when the interfering words were presented after the presentation of the target words. The children with SLI demonstrated a late semantic inhibition effect that was not observed in the children with TLD. This suggests that the semantic competitor words remained active for a longer duration for the children with SLI causing interference by the activation of items that are not needed or not the ultimate target. This may be one cause of slow processing seen in SLI.

Poll *et al.* (2014) examined whether adults with SLI would show a slower decay rate than their typical language peers in a sentence processing task. Grammatical sentences were presented to the participants with a target word embedded. When the target word was heard, participants pressed a response button. There were two conditions at which sentences were presented, a normal rate and slow rate. Poll *et al.* (2014) found that the response times increased between the normal and slow rate condition for both adults with typical language and those with SLI. They also found that the adults with SLI were slower to respond than their typical language peers at both the normal and slow rate conditions, but the difference in response time for the slow rate condition was smaller. That is, an abnormally slow rate of presentation was less difficult for the individuals with SLI. This perhaps was due to a longer activation for the target word over time, which also may explain a smaller increase in response time. Poll *et al*. (2014) found the findings consistent with their hypothesis of a slower decay rate for those with SLI.

In contrast to the above findings, a study by McMurray, Samelson, Lee & Tomblin (2010) suggested that differences found between individuals with language impairment and their typically developing peers were due to a faster decay rate of memory traces. In this study, eye movements were observed during a verbal word recognition task and monitored in real-time to determine the strength of the interference from potential competitor words. They discovered that adolescents with a language impairment had fewer eye gazes to the target words and more looks toward the three other word competitors offered (an onset competitor, rhyming competitor, and an unrelated word). McMurray *et al*. compared their results to 12 computational models highlighting different potential areas of deficit. They found the approach that best fit their data was the model of fast lexical decay. Other models that also fit their data, albeit less well, included impairments at sensory and phonological levels, vocabulary size, and generalized slowing.

Thus, there has only been a handful of studies that have examined decay rate and interference as possible underlying factors to determine the language profile of SLI, and each of the above noted studies used different methods in their research. Moreover, while two of these studies (Seiger-Gardner & Schwartz, 2007; Poll *et al.*, 2014) found that slow lexical decay best fit their data, McMurray and colleagues (2010) concluded that their data were more consistent with fast decay. The study by McMurray and colleagues demonstrated the feasibility of eye gaze patterns is a potentially useful methodology for studying the processes that support language use.

While many researchers have investigated language processing using a variety of techniques, few have focused on eye-tracking technology to examine eye gaze patterns and duration in relation to language processing activation. Studying eye gaze is valuable because it can provide information about complex cognitive processes by measuring where a person is looking. This is known as the eye mind hypothesis (Rayner, 1998). Information can be gained about visual attention as processing is taking place (Venker & Kover, 2015). It is known that people usually look at what they are thinking about (Griffin & Davison, 2011). Monitoring eye movements may help to study word and utterance planning - processes that typically are not observable.

Research Questions and Hypotheses

This present pilot study employed eye-tracking to examine the gaze patterns of children with SLI compared to their typically developing peers as they named pictures on a screen. Children with SLI are generally slower and less accurate than their typically developing peers on naming tasks (Leonard, 2014; Seiger-Gardner & Schwartz, 2007, Leonard *et al.,* 1983). However, despite being slower, the performance of children with SLI is affected in similar ways by the same variables as typically developing peers (Leonard, 2014). For example, Leonard *et al.* (1983), reported that the effect of the frequency of occurrence for each of the words were similar across children with SLI, their age-matched peers, and language matched peers. Gaze patterns can play a role in helping to elucidate why children with SLI are slower to name pictures.

The aim of the current study is to gain further insight into the processing challenges that may underlie the performance profile of children with SLI. In keeping with the previous literature, we expect that children with SLI will name pictures more slowly and with a higher error rate than typical age-matched peers. This would result in overall slower naming latencies for the children with SLI compared to the typically developing children.

A typical gaze pattern for naming and talking about objects is to look at the picture you are about to name or describe before talking about it (Griffin & Bock, 2000; Griffin & Oppenheimer, 2006). Meyer, Sleiderink, & Levelt (1998), for example, looked at participants' eye movements as they named two objects on a screen. They reported that the participants named the first object about 260 ms after they moved their gaze to the second picture. We expect to see a similar pattern in the typically developing children in this present study. We anticipate that they will look at the first picture to be named, and shift their gaze to the next picture to be named just prior to speech onset (although the time course may differ from that reported by Meyer et al., 1998). There are two main gaze patterns that we could potentially see in children with SLI. The children with SLI may look at the first picture to be named, name it, and then begin looking at the next picture. This would be consistent with fast decay because the child is not able to hold that picture in their mind long enough to name it if they are not looking at it. This would contribute to slower naming times because the child must finish naming an object before they can begin looking at the next picture to be named. A second potential gaze pattern we might see in children with SLI is for the child to look at the first picture to be named, name it as they are starting to look at the next picture, but look back to the picture that they just named. This would be consistent with a slow decay because the child is not able to let go of the picture that they just named, so they make more glances back to what they already named.

We anticipated that children with SLI would show different looking patterns during lexical access than their typically developing peers. More specifically, we expected children with SLI to look back to the previously named pictures more often and gaze at these pictures for longer than their peers during the planning phase of the next target word. This pattern would be consistent with interference-based challenges. This study will add to the current body of research on the possible causes underlying language processing differences of children with SLI and how these differences may contribute to their language development challenges.

METHOD

Participants

Participants for the study were 5 children with SLI and 3 typically developing peers. The typically-developing peers were, overall, somewhat younger than the participants with SLI. All participants were monolingual English speakers. The children with SLI (age range 5;8 - 7;0) met the following criteria: (a) a standard score of at least 1.5 SD below the mean on the Expressive Language Scale of the Clinical Evaluation of Language Fundamentals, Fourth edition (CELF-4), and (b) a score within 2 SD of the mean on the Nonverbal Matrices Scale of the Kaufmann Brief Intelligence Test (KBIT-2). The comparison group consisted of 3 children with typically developing language (age range 4;10 - 6;3). TD participants met the following criteria: (a) a standard score no more than 1 SD below the mean on Expressive Language Scale of the Clinical Evaluation of Language Fundamentals, Fourth edition (CELF-4), and (b) a score within 2 SD of the mean on the Kaufmann Brief Intelligence Test (KBIT-2), and (c) no previous history of language delays or disorders. All the children in the study passed a hearing screen in both ears. All children completed the Expressive Vocabulary Test - 2nd Edition (EVT-2, Williams, 2007). EVT-2 scores were collected to help further describe the language profiles of the two groups, and were not used as inclusionary or exclusionary criteria. The mean standard score of the children in the SLI group was 89.6 (*SD* = 6.59); for the children in the TD group it was 117.67 (*SD* = 8.73). Table 1 presents the test scores of each participant. SLI participants were recruited from a local school for children with speech and language impairments. The children with typical language development were recruited via local advertisements and word of mouth.

Table 1. Summary of Participants' Test Scores

CHILD	AGE (Y; M)	TESTS				
		CELF-4 Core Language	CELF-4 Expressive Language	EVT-2	KBIT-2	Hearing Screen
SLI 102	6;8	64	63	89	116	pass
SLI 104	6;10	70	67	84	81	pass
SLI 105	6;5	58	59	81	85	pass
SLI 106	5;8	83	75	98	100	pass
SLI 111	7;0	62	53	96	84	pass
Mean	6;5	67.4	63.4	89.6	93.2	
SD	5 months	8.71	7.42	6.59	13.17	
TD 202	6;3	114	117	127	96	pass
TD 303	4;10	118	109	120	110	pass
TD 305	5;5	129	123	106	109	pass
Mean	5;5	120.3	116.33	117.67	105	
SD	7 months	6.34	5.73	8.73	6.38	

Materials

This study used an *SR Research Eyelink 1000 Plus* remote eye tracker to monitor the eye gaze patterns of the children. A 500 Hz sample rate was used. For all children, the left eye was tracked.

The experimental stimuli consisted of 30 child-friendly colour pictures of familiar objects. These pictures were grouped into sets of three for presentation. Age of acquisition (AoA) and frequency of the referent lexical items were balanced as much as possible within each set of three pictures (Mean AoA: 30.4 months; Mean frequency: 237). AoA was defined as the age in months at which 75% of parents report production of a word on the MacArthur-Bates CDI (MCDI, Dale & Fenson, 1996), or when not available, the 6-month age band at which 75% of children were successful at naming an item in the study reported by Morrison, Chappell, & Ellis (1997). Frequency was recorded as the number of occurrences of a word per million words in the ChildFreq database (Bååth, 2010). See Appendix A for the list of stimulus items and their AoA values and frequency. The presentation order of the sets and the order of the pictures within each set was randomized for each child by the experimental presentation software. For all the experimental trials, a small jewel-like fixation point centred over where the leftmost picture would appear served as a fixation cue of where the child should begin looking.

Procedures

Pictures in sets of three were presented on a computer monitor for the children to name. The pictures were distributed horizontally, at equal spacing at the vertical midline of the monitor. On each trial, a circle or square appeared in the fourth position. The child named each experimental stimulus and the circle/square. The purpose of the shapes was to provide a reason for the children to shift gaze away from the third picture after they had finished processing it, rather than simply resting their gaze on the third picture as the last item on the screen. Prior to the experiment proper, children were introduced to the stimuli and their anticipated labels in a familiarization task. The pictures were arranged with six to eight pictures on a page. The children were told, "*You are going to see some pictures on the computer and it* *will be your job to say what each one is. First, we're going to show you all the pictures so that you know what each one is.*" The examiner named a picture on the page and the child pointed to the picture that was named. If the child got a picture wrong, that item was returned to at the end after the child had gone through the rest of the pictures. After the child was familiarized with all the pictures, his or her eye movements were calibrated.

Three demonstration trials were conducted to familiarize the child with the procedure. To begin, each child was given the following instructions about the task, *"You are going to see some pictures on the screen, going 1, 2, 3, 4, across the screen and your job is to say what each one is as soon as you know. The last picture will always be a circle or a square, but the other pictures will change. We're going to practice first so that you know how the game goes and so we can make sure the computer is working properly."* In these trials, the experimenter named the three target pictures on the screen from left to right. A fourth picture, either a circle or a square, ended each trial. Each child completed five practice trials before beginning the experiment. The first three practice trials contained the same stimuli as the demonstration trials. The child received feedback as needed about the order in which they named pictures. To facilitate the correct order for naming, an arrow was placed under the pictures to indicate the left to right movement in both the demonstration and first three practice trials. Practice trials four and five contained new stimuli and did not include the arrow indicating the order. The goal was to have the child independently name the three target pictures in left to right order by the fourth and fifth trial. If the child could independently name the three pictures correctly in order, the experimental trials began.

The beginning of each trial was signalled with a pure tone beep and ended, after naming the three pictures, when the child named a shape (circle or square). All trials were manually advanced. The experimenter did not begin the onset of the next trial unless the child was still attending to the task. An inter-trial screen allowed the experimenter to clear the completed trial, without proceeding directly to the next trial.

Transcription and Coding

The participants' responses were transcribed orthographically to a spreadsheet. If the response differed from the target for any of the three pictures in a trial, the entire trial was removed. Near synonyms such as 'plane' for the target word 'airplane' and 'hairbrush' for the target word 'brush' were noted and accepted. From the recordings, we determined the response onset latency for each picture by measuring the waveform using the program, *Audacity*. For the first picture in a set of three, onset latency or response time (RT) was determined as the time to speech onset from the start of the trial. For the second and third pictures in a set, the RT was measured as the elapsed time from the onset of the previous response. Responses that included an initial consonant repetition (e.g., s-s-s-star) or a filler (e.g., umm spoon) were noted and accepted if the onset latency of the final response occurred within 5000 milliseconds. Any responses that took longer than 5000 milliseconds were noted and the entire trial was removed. Transcription and coding of the SLI participants was done using a consensus approach. Two raters transcribed and coded the onset times of 2 and 3 SLI children's files respectively and recorded them on the excel document. To confirm reliability, a second rater checked the transcription and RT values, any discrepancies were noted and resolved through discussion. Once this procedure had established consistency in transcription and coding between the two experimenters the remaining TD children's files were each transcribed by a single experimenter following the established protocol.

RESULTS

Accuracy

Accuracy for naming the pictures was high for both the SLI group and the typically developing peer group as shown in Table 2. The children with SLI and their typically developing peers both averaged an accuracy of 97 percent (*Range:* 93 - 100%).

Table 2. Percent Accuracy for Naming of Pictures

CHILD	# of errors*	Total # of words	Accuracy %
SLI 102	1	30	97
SLI 104	2	30	93
SLI 105	1	30	97
SLI 106	0	30	100
SLI 111	1	30	97
Mean			97
TD 202	2	30	93
TD 303	1	30	97
TD 305	0	30	100
Mean			97

* misnamed picture errors

Response Time

The mean response time for each picture (i.e., 1, 2, 3) for each participant was analysed to determine if any pattern in the speed of naming between the typically developing participants and the children with SLI could be established. In Table 3, the mean reaction times are given for all participants. The mean response times for each of the children with SLI and their typically developing peers are shown in Figure 1 and Figure 2 respectively. Further, the overall mean response times for the SLI group compared to the typically developing group are shown in Figure 3. Table 3 and Figure 3 show that, descriptively, the mean response time per picture was slower for the SLI group compared to their typically developing peers, with the SLI group being 146, 98, and 188 ms slower than their typically developing peers for picture 1, 2 and 3 respectively. However, as seen in Table 3, Figure 1 and Figure 2, on an individual basis there was considerable overlap in response times between the two groups. There was also no obvious difference between the groups in the pattern of response times across responses. Indeed, when looking at the mean RTs per picture, for both groups we see numerically longest latencies for the first picture followed by decreasing latencies for subsequent responses.

Table 3. Mean Response Times, ms - All Participants

CHILD	PICTURE		
	1	2	3
SLI 102	1470	1274	1396
SLI 104	1730	1702	1843
SLI 105	1470	991	1223
SLI 106	1680	1896	1319
SLI 111	1057	949	919
Mean	1481	1362	1340
SD	265.5	423	334.5
TD 202	1023	1332	1000
TD 303	1581	1427	1640
TD 305	1402	1035	815
Mean	1335	1265	1152
SD	285	204	433
DIFF*	146	98	188

*Difference in mean response time between groups in ms

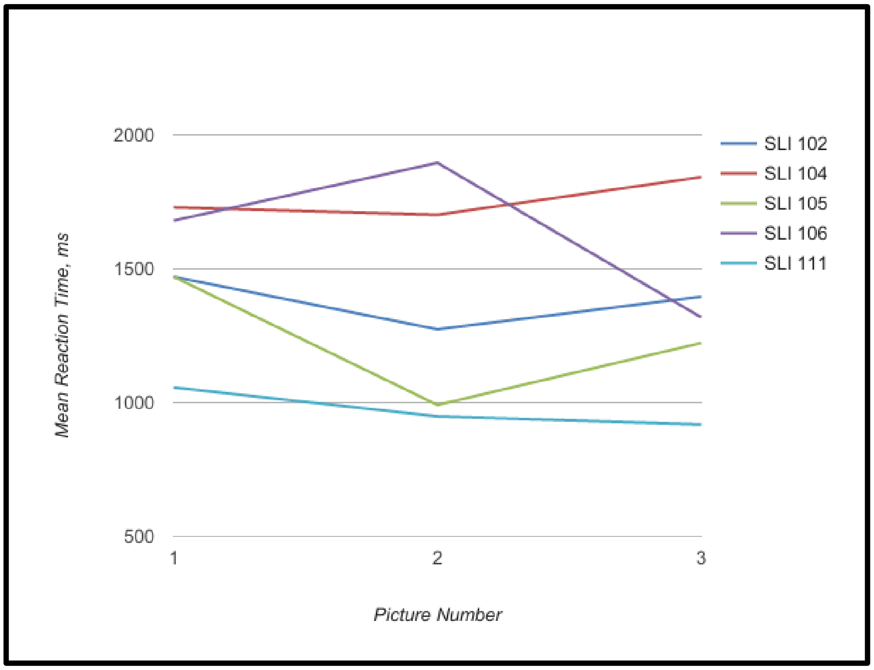

Figure 1. Mean Reaction Times, ms - Children with SLI

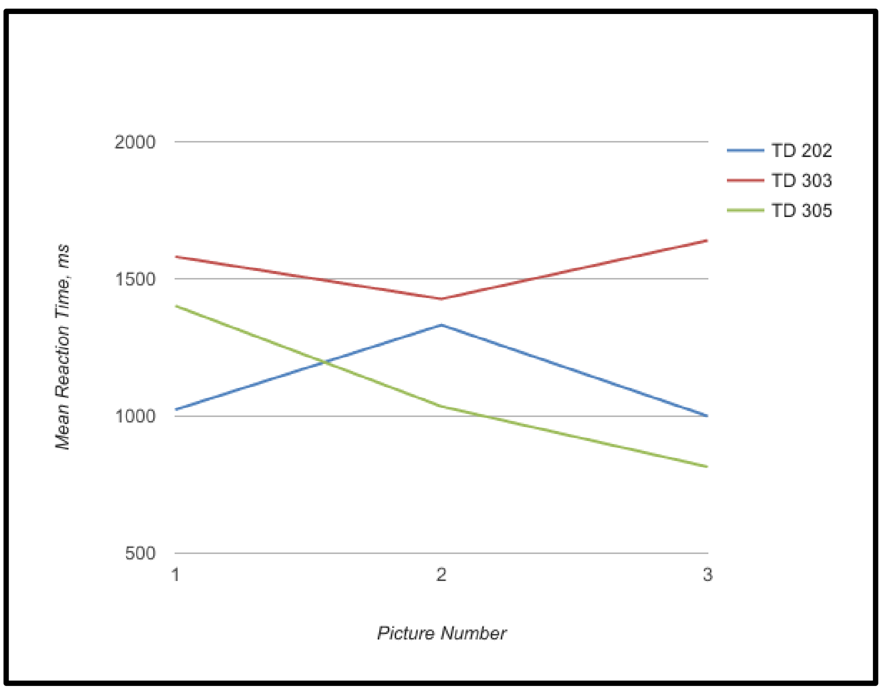

Figure 2. Mean Reaction Times, ms - Typically Developing Peers

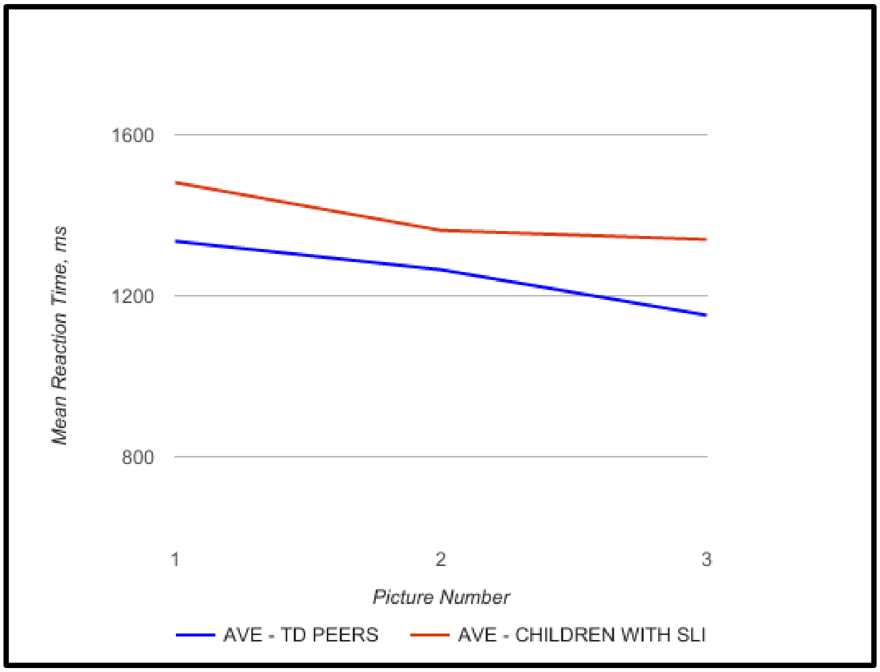

Figure 3. Overall Mean Reaction Time, ms - Children with SLI compared to typically developing peers.

Eye Gaze Data

Gaze data were available for each 2 ms of viewing time during the experiment. For analysis purposes, proportions of looks to each picture were averaged or "binned" over successive 50 ms intervals. The proportion of looks within each 50 ms bin to each picture in each trial was determined and summed across all trials. Eye gaze data were unavailable for participants 102 and 104 due to technical problems with data capture.

Figures 4 to 6 of Appendix B show the eye gaze patterns for each of the children with SLI when naming each of the three pictures. For each child, a separate figure is presented for each picture position. The figures present data collapsed across trials, with the onsets all anchored at 0. The red, green and blue lines depict the proportion of looks to Pictures 1, 2 and 3 respectively. For the children with SLI, participants 105, 106 and 111 showed a typical looking pattern while naming objects. The proportion of looks to the picture they were about to name decreased just prior to naming it while the proportion of looks to the next picture increased.

It was hypothesized that if children with SLI had difficulty with interference from previous responses or slow decay, one might see ongoing or return gazes to previously named pictures. In Figures 4 and 5, slight increases of proportion of looks are seen after the naming of Pictures 1 and 2 as well as for Picture 1 in Figure 6 indicating return gazes to previously named pictures.

In Figure 7 to Figure 9 of Appendix C, the eye gaze patterns for each of the typically developing children are given while naming each of the three pictures. Each of the typically developing peers show expected eye gaze patterns while naming the objects. The proportion of looks to the picture they were naming decreased and they looked more to the next picture. With this set of data, the typically developing children seemed also to gaze more at Picture 3 while naming it than the children with SLI. Furthermore, increases in the proportion of looks for previously named pictures is also seen in Figure 7 (Picture 1) and Figure 8 (Picture 1 and 2). This indicates that the typically developing peers also looked back to previously named pictures.

Eye gaze data for each trial for each participant was also analyzed for similarities and differences in looking patterns between the two groups. Table 4 presents the average number of times from the point of onset of the trial or the onset of the previous named picture that the participants in each group looked ahead to subsequent pictures then back to the target picture, prior to the onset of naming the target picture (e.g., looking at Picture 1 then Picture 2 then back to Picture 1 before naming Picture 1 or looking at Picture 2 then Picture 3 then back to Picture 2 before naming Picture 2). This analysis approach can provide insight into task strategy/ the amount of advanced planning that the children completed. In addition, the average number of times participants in each group looked back to previously named pictures is also given. An occurrence was counted if a participant looked fully at a picture (proportion of looks being 1) for at least 50 ms or longer during the interval of interest. The SLI group more often looked ahead to unnamed pictures than the typically developing peer group (average of 0.88 versus 0.57 times). The SLI group also looked back to previously named pictures more often than the typically developing peer group (average of 0.38 versus 0.25 times). From the analysis, it appeared that the SLI group spent more time looking back and forth between pictures when trying to name them. As discussed above, the amount of looking to previously named pictures could be an indication of more difficulty with interference or slow decay. The higher amount of looking to subsequent pictures prior to naming the target picture could possibly be due to the SLI group typically requiring more pre-planning of the task or processing of the pictures before naming.

Table 4. Number of Occurrences of Different Looking Patterns

Group		Looks forward	Looks back
SLI	No. of occurrences	23	10
	No. of trial	26	26
	Ave. no. of occurrences	0.88	0.38
TD	No. of occurrences	16	7
	No. of trial	28	28
	Ave. no. of occurrences	0.57	0.25

In Table 5, the average length of time each of the groups looked at a picture before and after naming it is shown. The length of time a participant looked at a picture prior to naming it was the sum of eye gaze periods of 50 ms or longer where the participant was fully looking at the picture (i.e., proportion of looks of 1) taken from the trial onset until the onset of the target response. The length of time a participant looked back at a picture was the sum of eye gaze periods of 50 ms or longer where the participant looked fully at a previously named picture (i.e., proportion of looks equal to 1) taken from the onset of the target until the onset of Picture

3. On average, the SLI group looked at a picture longer before naming it than the typically developing group (Picture 1: 879 ms vs. 841 ms for the SLI and TD groups, respectively, Picture 2: 1069 ms vs. 811 ms, Picture 3: 1033 ms vs. 759 ms). Furthermore, there appears to be a difference in gaze on average to Picture 2 prior to naming Picture 3 for the SLI group compared to the typically developing group. One should note that these are not RTs but rather the sum of gazes to the picture in question.

Table 5. Average Length of Time Looking Before and After Naming a Picture

Group	Length of looking before naming			Length of looking after naming		
	Picture 1	Picture 2	Picture 3	Picture 1	Picture 2	Picture 3
SLI ave, ms	879	1069	1033	73	38	-
TD ave, ms	841	811	759	70	5	-

DISCUSSION AND CONCLUSION

The purpose of this study was to examine the eye gaze patterns of children with SLI as they completed a simple naming task, to develop a better understanding of the nature of their processing challenges during language planning and production. The participants' eye movements were tracked using an *SR Research Eyelink 1000 Plus* remote eye tracker as they named pictures presented in sets of three on a computer screen. Recordings of each child's verbal response were made and information on timing and accuracy was collected. Our results revealed that overall, the children with SLI had slower response times than the typically developing children. This finding is consistent with the current literature on the response time of children with SLI compared to age-matched peers (Leonard, 2014; Seiger-Gardner & Schwartz, 2007, Leonard *et al.,* 1983). When we looked at the gaze patterns of the children with SLI compared to the typically developing children, we expected the typically developing children to name each picture just after they had shifted their gaze to the next picture to be named. In contrast, we expected the children with SLI to either keep their gaze focused on the picture to be named before shifting their gaze to the next picture or to look back to the previously named picture before naming the current picture. The gaze patterns of both the typically developing children and the children with SLI on average showed that all the children started looking to the next picture as they were naming the current picture. This is considered a typical gaze pattern and one that we had expected to see for the typically developing children, but not the children with SLI. There were instances of increased proportion of looks to a previously named picture for the children with SLI which would be consistent with the slow decay hypothesis but this was also seen in the results for the typically developing group on average. Our results showed, however, that the children with SLI spent more time looking at each individual picture before naming it. This could indicate that the longer reaction times for children with SLI compared to typically developing children are due to processing differences. They required more time to retrieve the label for the pictures they were looking at.

No obvious difference between the groups in the pattern of response times across responses was found. Both groups took longer to name the first picture and latencies decreased for subsequent pictures. The longer response times for Picture 1 across trials for both groups could be due to a similarity in task planning. In looking at the individual eye gaze data for both groups, a common pattern among participants in both groups was to look at Picture 1 and then at subsequent pictures (typically Picture 2) before returning to Picture 1 ahead of naming it. Time taken to look ahead to other pictures would increase the latency for Picture 1. This pattern rarely occurred prior to naming Picture 2 and eye gaze data for the shape after Picture 3 was not analyzed. Though both groups used this strategy to possibly plan the task, it was found that this strategy was used less often by the typically developing peer group. Possibly, the SLI group required more pre-planning of the task or processing of the pictures than the typically developing peer group.

It was also hypothesized that the children with SLI would make more errors in naming than their age-matched peers. However, no differences were found between the groups. Both the SLI and typically developing group showed the same accuracy for naming the pictures.

We had additionally expected that the children with SLI would demonstrate more looks back and would spend more time looking back to the previously named pictures compared to the typically developing children. We found that both groups looked back to previously named pictures but indeed the children with SLI demonstrated more looks back than their typically developing peers. The looks back to previously named pictures could be an indication of slow decay in which the children with SLI are unable to let go of the picture they had already named and so they spend more time looking back at the previously named pictures.

Another hypothesized potential gaze pattern for children with SLI would have been for them to look at the target picture and name it, before looking to the next picture to be named. This was expected if the child had to remain looking at the picture to hold it in mind long enough to name it which would be consistent with fast decay. In this study, however, it was found that the typically developing group continued gazing at a picture right up to or even past the onset of the response.

Conclusions

In this present study, the typical eye gaze pattern for naming pictures was found for both groups. The participants on average looked at the picture to be named and as they started to name it, looked to the next picture. Additionally, eye gaze patterns in support of fast and slow decay were seen in both groups. Both looking back at previously named pictures and looking while naming before moving on to the next picture occurred within both groups. However, the occurrence of these patterns differed between the two groups with the pattern supporting fast decay occurring more often among the typically developing group and the pattern supporting slow decay occurring more often among the SLI group. A main difference between the eye gaze patterns between the two groups was length of time looking at the pictures. The SLI group typically looked longer at pictures before naming them as well as spent more time looking back at pictures previously named. The findings in this study are compatible with slower response times seen for children with SLI being due to longer processing times and interference-based challenges.

There has only been a handful of studies that have used eye-tracking to analyze language production. This study adds to that body of literature by extending the range of questions that have been addressed using eye-tracking technology. It demonstrates the feasibility of this approach and suggests that future research on this question, with a larger sample is warranted. However, there are several drawbacks specific to using eye tracking that should be noted. Often, it can be difficult to get children to cooperate due to the confinement of the equipment. Future researchers should be aware that technical issues can arise when using eye tracking technology which makes gathering eye tracking data time consuming.

Potential limitations of this study include the small sample size and differences in the average age between the children with SLI and the typically developing children. It is difficult to draw strong conclusions based on a limited sample size and more patterns may become evident with a larger group of participants. More research is needed in this area to further study the processing challenges of children with SLI.

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APPENDICES

Appendix A. Word list with age of acquisition (in months) and frequency values. AoA values indicated by * are taken from the data reported by Morrison et al. (1997); otherwise AoA data are taken from the MCDI (Dale & Fenson, 1996).

	Age of Acquisition	Frequency
Set 1		
candle	38.5*	41
pillow	28	79
towel	38.5*	41
Set 2		
star	30	140
key	>30	89
bowl	28	140
Set 3		
flower	24	199
airplane	24	148
bottle	22	108
Set 4		
house	22.1*	1133
ball	23.4*	444
car	22.1*	1260
Set 5		
brush	28	89
sock	30	84
doll	27	109
Set 6		
ring	50.5*	184
heart	50.5*	110
shirt	56.5*	302
Set 7		
clock	30	77
train	28	214

stick	30	400
Set 8		
bike	26	131
soap	28	52
leaf	25.1*	136
Set 9		
hammer	30	70
pencil	30	120
castle	38.5*	92
Set 10		
spoon	24	250
hat	24	441
book	20	528

Appendix B. Eye gaze patterns for the children with SLI when naming each of the three pictures.

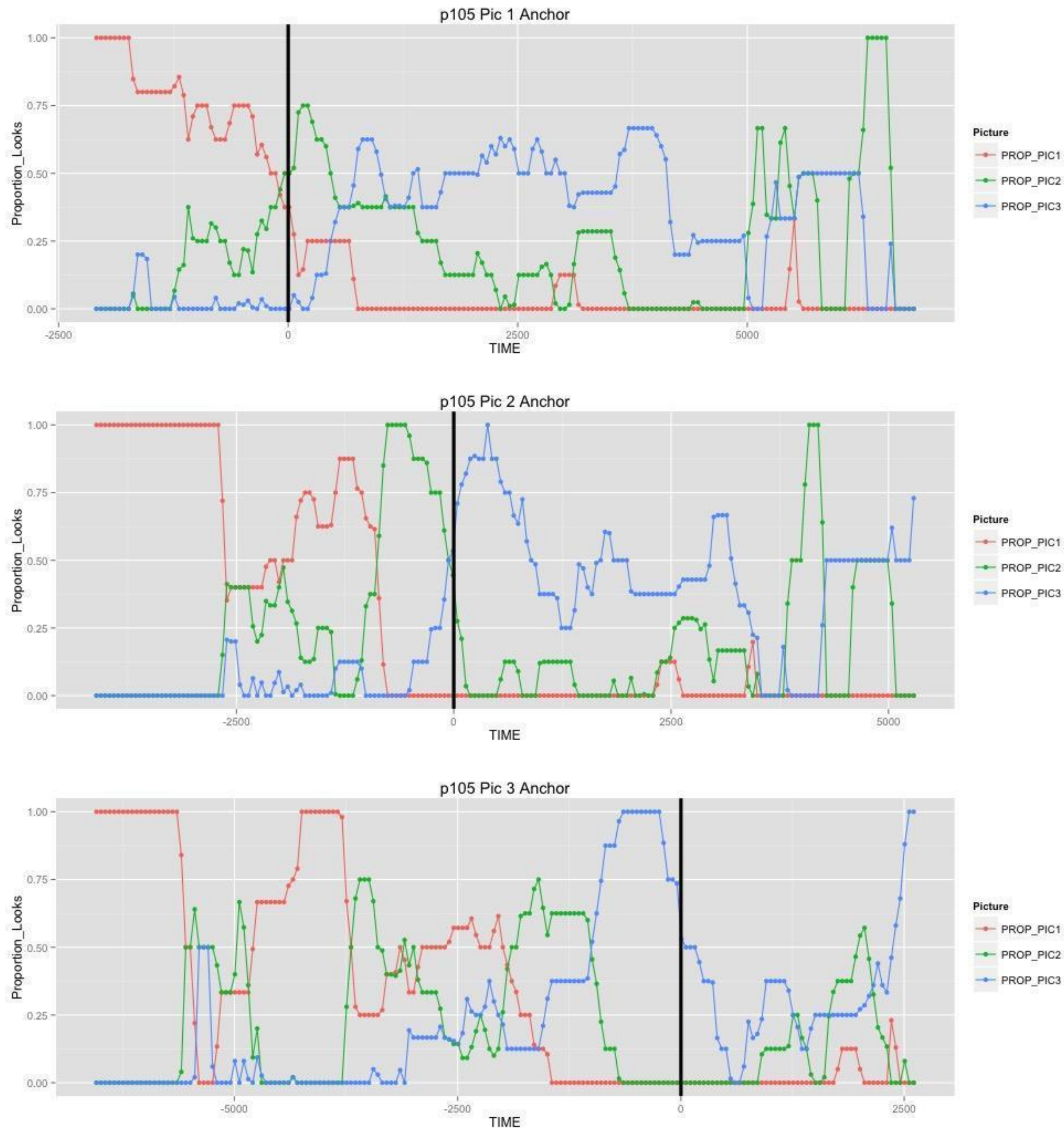

Figure 4. Proportion of looks for participant 105 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participant's production of the picture naming response.

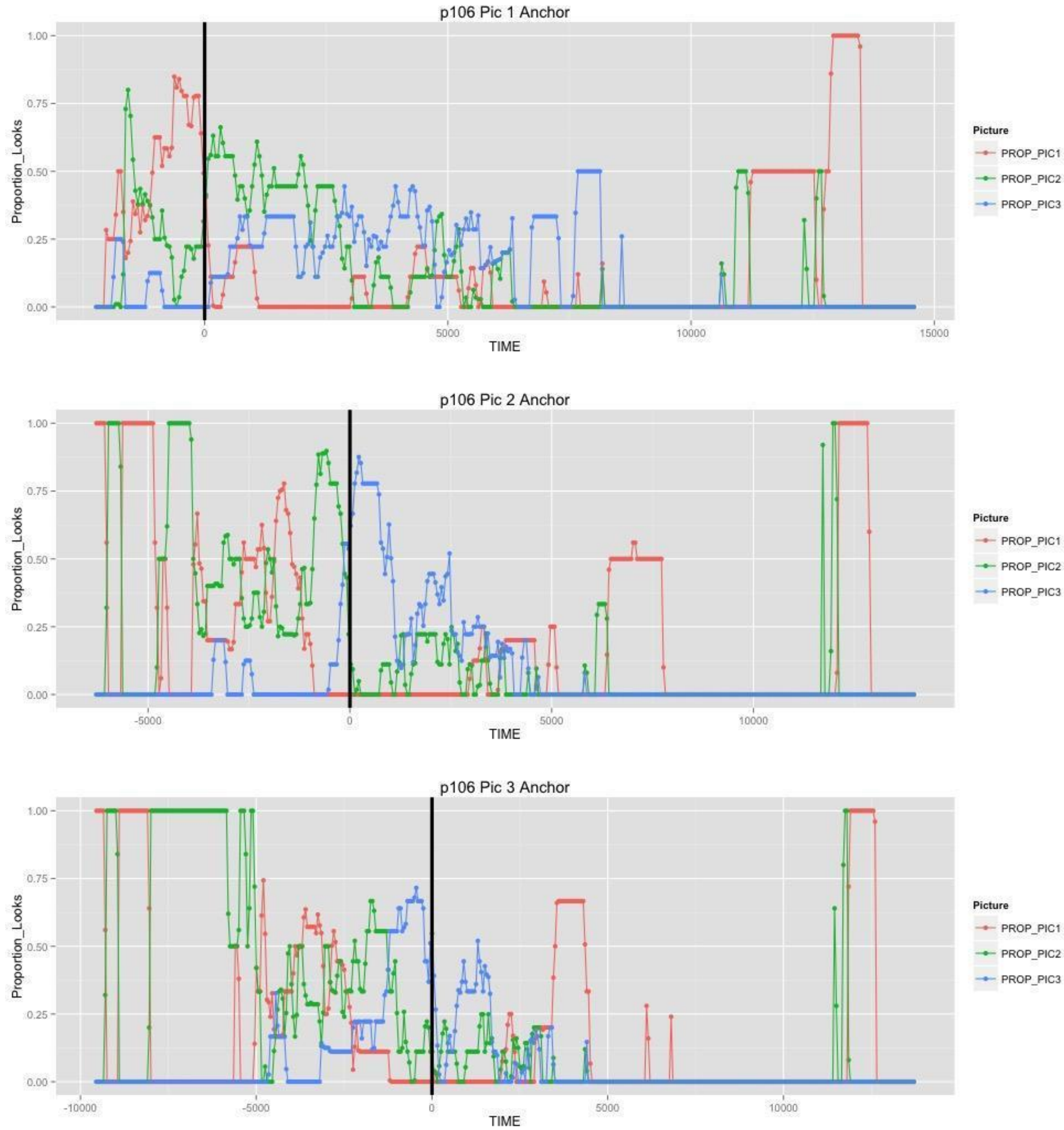

Figure 5. Proportion of looks for participant 106 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participants production of the picture naming response.

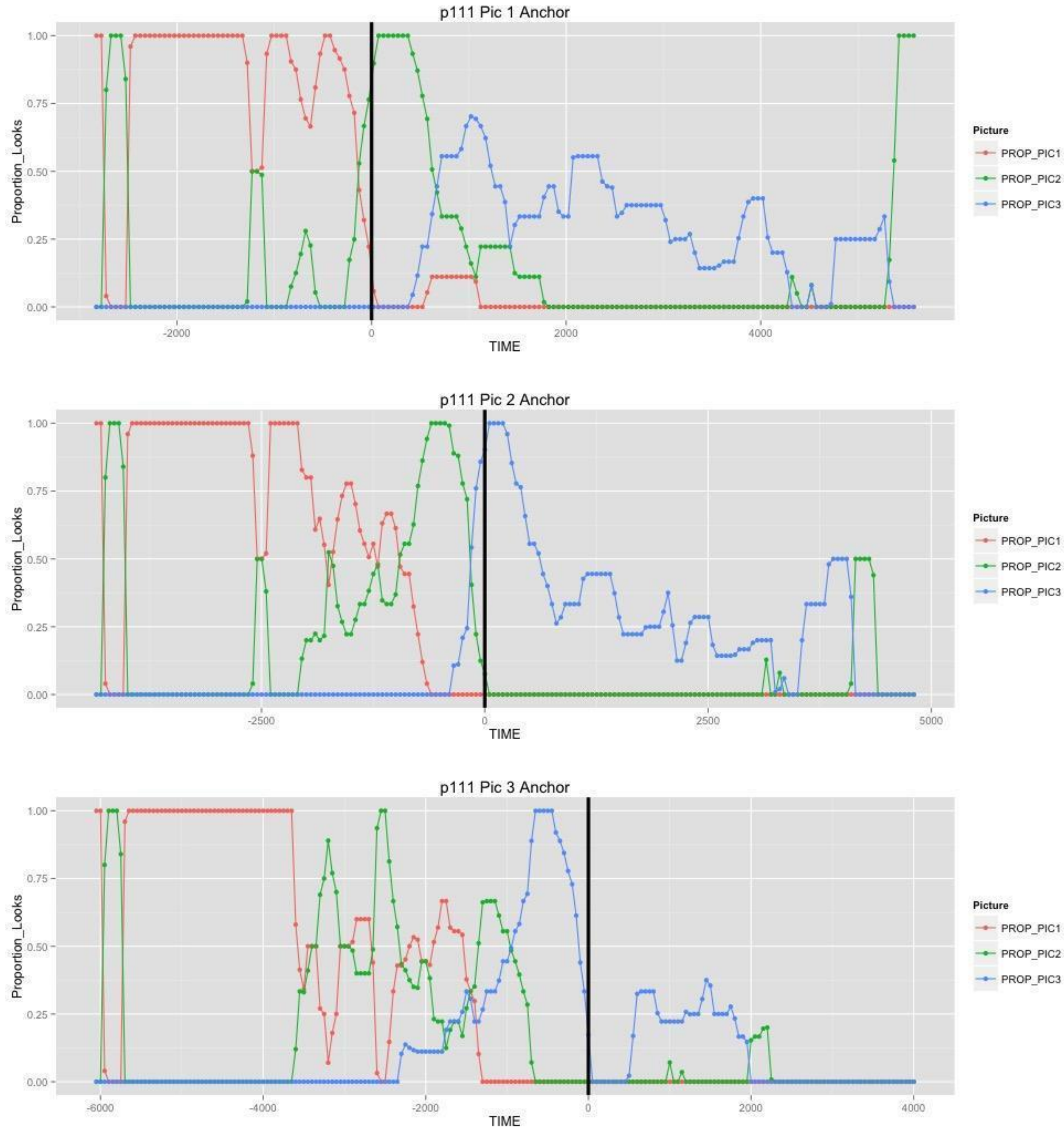

Figure 6. Proportion of looks for participant 111 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participants production of the picture naming response.

Appendix C. Eye gaze patterns for typically developing peers when naming each of the three pictures.

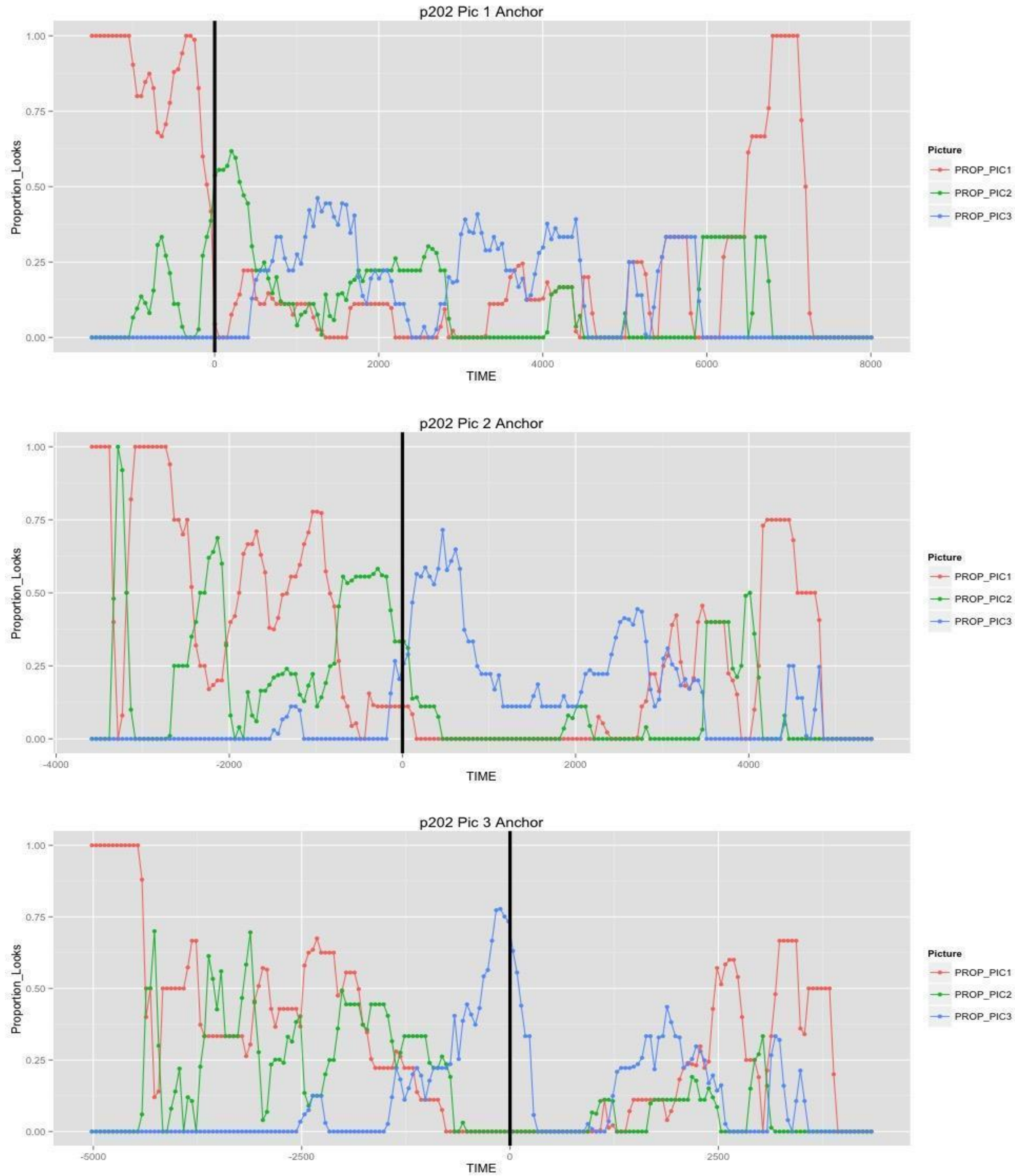

Figure 7. Proportion of looks for participant 202 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participants production of the picture naming response.

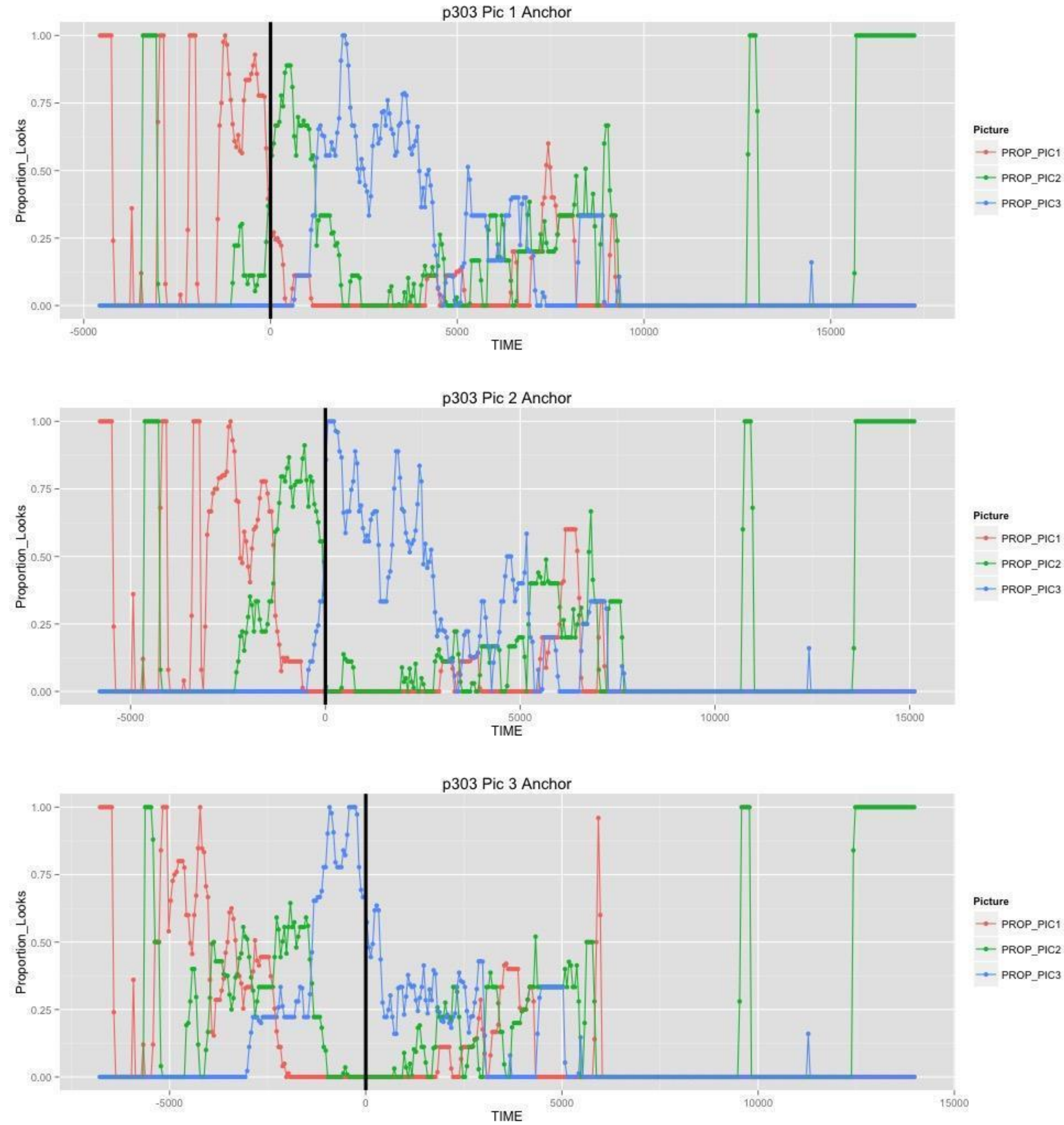

Figure 8. Proportion of looks for participant 303 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participants production of the picture naming response.

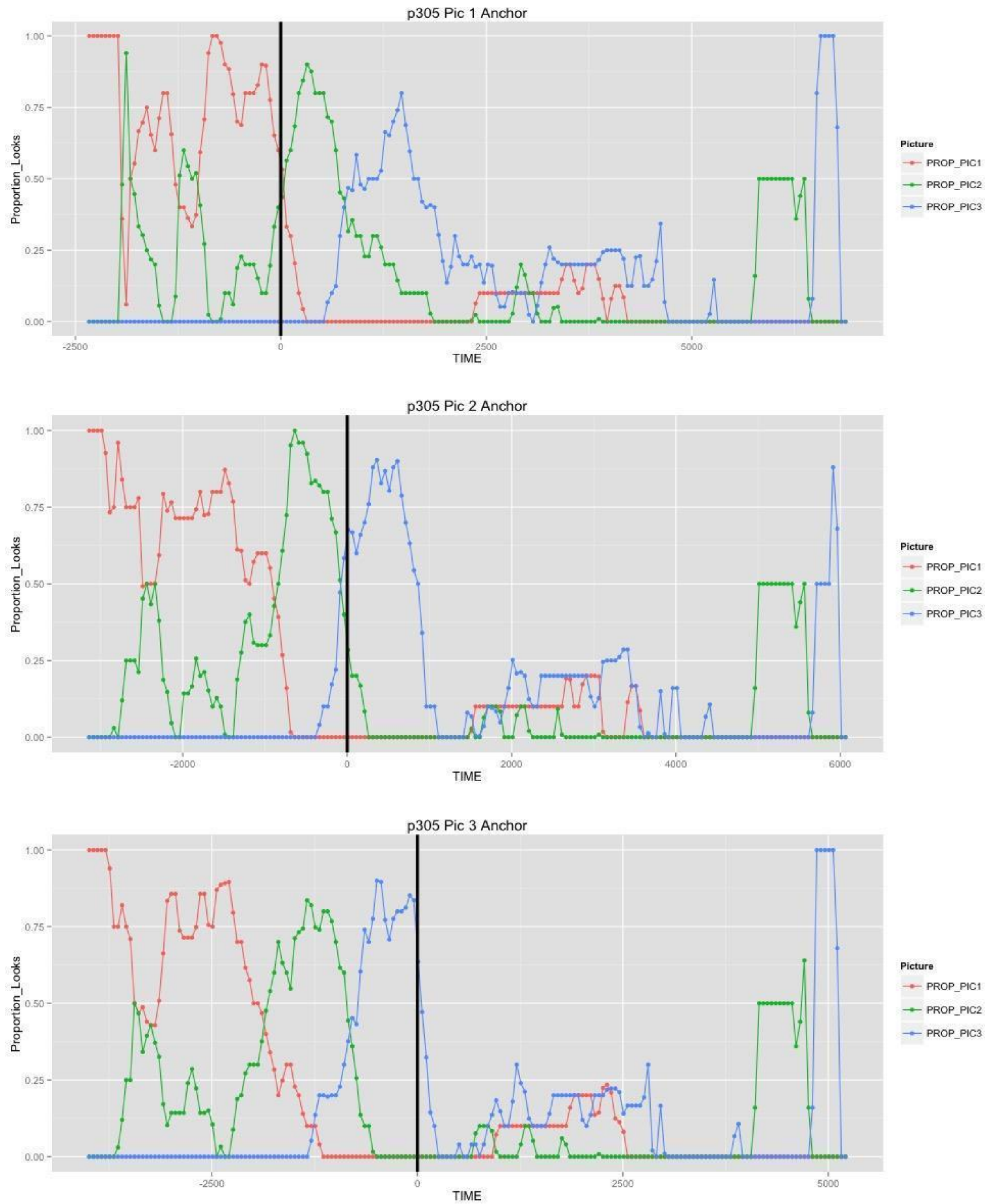

Figure 9. Proportion of looks for participant 305 across all trials for each of the three pictures. The solid line at time 0 indicates the onset of the participants production of the picture naming response.