CHANGES IN CLICK MIGRATION AS A FUNCTION OF AGE:
Implications for the Development of Speech Perception*

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ABSTRACT

The purposes of this study were 1) to determine the ability of children of various ages to perform a click location task;and 2) to analyze the click migration patterns for S's who were successful in the click location task. With an ANOVA design five age groups were tested. Significant results were obtained indicating that a) all experimental groups were able to successfully perform the click location task; and b) there were unexpected differences in the amount of click migration as a function of age. Results are discussed in terms of their implication for speech perception.

In 1960, Ladefoged and Broadbent, searching for ways to study speech perception, devised a method in which a click of specified duration (usually 30 msecs or less) would be recorded in such a manner that it would be "superimposed" in specific portions of a word in either sentences or word strings. Subjects were then asked to locate the click relative to the co-occurring speech stimuli. This method of click location has since been adopted by many researchers in the area of speech and language perception. Bever and his colleagues (Abrams & Bever, 1969; Bever, Lackner & Kirk, 1969; Fodor & Bever, 1965; Fodor, Bever and Garrett, 1974) have used this click location technique extensively in their investigation of units of language perception. They found that when subjects were asked to locate clicks placed symmetrically around and in the major constituent break of complex sentences, these click locations would move or "migrate" toward or into the major breaks. These researchers speculated that the linguistic knowledge a subject possesses limits his ability to perceive the superimposed click until points in time where closure can take place, i.e., the major syntactic break of the test sentences.

Reber and Anderson (1970), Holmes and Forrester (1972), and Chapin et al (1972), began to question the Bever data since the results of their studies failed to produce the patterns reported by Bever, et al.

Seitz (1972) and Seitz and Weber (1974) reviewed many of the click location studies and found that those researchers who required their subjects to write out exactly or repeat back exactly the stimulus strings before marking the click location, reported movement toward the major constituent breaks; while those researchers who had the subjects mark prepared scripts or rewrite the word on which the click was thought to occur showed various other types of click movement. In 1972, Seitz suggested that these divergent findings may not truly be in opposition, rather it may be that different response requirements affected both the direction and subjective location of clicks and the interpretation of the data. It seemed possible and probable that the different response requirements created different expectancy sets and as a result, the researchers may not in reality be testing the same perceptual tasks. The Seitz and Weber (1974) study strongly supported this contention.

While criticism and debate continue to surround click location technique, no one has questioned or investigated the relationship of age or linguistic development to a subject's ability to do the click location task. Keeping this in mind, we felt that one good way to investigate the usefulness of the click location methodology in speech perception research was to explore the development of a subject's ability to do the click location task itself, thereby hopefully learning more about the development of speech perception.

A review of the literature indicated that all subjects previously used were adults or possessed adult grammatical abilities. (This is understandable when one recognizes that task requirements required writing or reading sentences, and that most researchers had access to university or military personnel for subjects.)

The present method involves a shortening of the length of the stimulus sentences and only requires the subjects to orally repeat these sentences thus allowing the testing of younger groups of children. We hypothesized that a general developmental pattern would occur, with a child's ability to successfully perform sentence and click location task increasing with age.

Summarizing, there were two major purposes for this study; a) to determine if a subject's ability to perform a click location task that requires accurate repetition of the stimulus sentences before click location takes place varied as a function of their age and b) to analyze any click migration patterns resulting from the successful sentence repetitions, for any indications of age related differences in speech perception.

EXPERIMENTAL DESIGN

Subjects

Five groups of subjects ranging in age from 7 years to 31 years were selected. The groups mean age and grades were:

School Grade	Groups	Mean Age	Age Range
1	Grp 1	7.0 yrs.	6 yrs. 8 mo. to 7 yrs. 4 months.
III	Grp 2	9.1 yrs.	8 yrs. 8 mo. to 9 yrs. 10 months.
V	Grp 3	10.9 yrs.	10 yrs. 1 mo. to 11 yrs. 7 months.
VII	Grp 4	13.2 yrs.	12 yrs. 10 mo. to 13 yrs. 6 months.
Adult	Grp 5	31.3 yrs.	22 yrs. 0 mo. to 46 yrs. 2 months.

The children's group came from grades 1, 3, 5 and 7 respectively. All participating children were performing grade level work and none had any reported language or learning difficulties. The adults were advanced university students or colleagues of the Experimenters. All groups contained 4 males and 4 females; all subjects were right handed and passed a hearing screening test in the speech frequencies. In all cases English was the subjects' first language and their language of instruction.

In addition to the five experimental groups, there was an additional group of Special Subjects whose data will also be discussed and plotted on the figures along with the experimental groups. However, only data collected from subjects in the five experimental groups were submitted to statistical analysis and any significant differences that will be reported and discussed apply only to these groups. This last group was composed of 8 children drawn from a special class for children with language learning difficulties. There were 3 females and 5 males in the group. Mean age for this Special Group was 10 years, 7 months. The reports on these children indicated that six out of eight had diagnosed problems in the area of auditory perception, including disturbances in auditory discrimination, auditory retention span, auditory processing and decoding. Two of the males were identical twins. While all the children's Full Scale WISC scores fell within the normal range, all had depressed Verbal versus Performance scores. One boy was a moderate spastic quadriplegic and one boy was suspected of having a hearing loss although the difficulties he demonstrated on the present task were not indicative of problems in the areas of auditory acuity. All of the other children's hearing was within normal limits. One of the girls had recently been integrated into a regular class. All showed a relatively good proficiency in English during observation and testing periods, and all had been attending school or receiving language help in English for at least two years. The rationale for inclusion of this group was to see if the click location method might be useful in studying speech perception in language disordered children. Thus, this Special Group, while not included in the statistical analysis with the five experimental groups, did participate in identical testing procedures and data analysis.

Sentences

Stimulus sentences were 24 eight-word sentences with surface structure major constituent breaks occurring between either the third and fourth, fourth and fifth, or fifth and sixth words. (See Appendix A.) All words within a two-word distance on either side of this break were monosyllabic. The sentences were recorded on one channel of a Sony TC 252 stereo tape recorder. Special care was taken to ensure that each sentence was read at the same rate and with minimal stress or intonational differences to prevent inadvertent effects on click movement. Recorded on the other channel, at one of three designated positions, was a click of approximately 20 milliseconds duration. Click positions were: 2 words **before** the major constituent break (Position a), **in** the major constituent break (position b and 2 words **after** the major break (Position c). The clicks themselves were recorded in such a manner as to always occur over the vowels of words for click positions (a) and (c) and between the terminating vowel/consonant and the initial consonant/vowel structure for click postion (b), the major constituent break.

a b c

Example: The small scared girl - sat in the corner.

One click position was specified for each of the 24 sentences, and was marked on the tape with a strip of foil which triggered a click generator. This was recorded on the second channel of the stereo tape recorder, coinciding with the designated click position on channel 1 of the stimulus tape. Click positions were eqully distributed so that 8 sentences had the click located in Postion (a), 8 at Position (b), and 8 at Position (c). In addition, 8 of the sentences contained the major break between the third and fourth words, 8 between the fourth and fifth words, and 8 between the fifth and sixth words. Click positions and major syntactic break locations were counter balanced on the stimulus tape.

Sentence Presentation

Each subject was tested individually in a quite room. Stimulus material was presented through Sony DE-7 headphones at approximately 40 dB Sensation Level. Subjects heard the sentences in one ear and the click in the other. Stimulus presentations were counterbalanced so that half of the subjects in each group heard the sentences in the left ear and the click in the right ear, and the other half heard the click in the left ear and the sentences in the right ear.

All subjects were instructed to listen carefully for both the click and the sentence. After each sentence the tape recorder was stopped and subjects were required to repeat back the sentence exactly as they heard it, and then to indicate on which word or between which words they thought they heard the click. All of the subjects' responses were recorded on a Sony cassette tape recorder to be transcribed and marked later. Five practice sentences were given at the beginning to ensure that subjects understood the task.

Data Analysis

Results were tabulated for accuracy of sentence repetition, accuracy of click location, and amount and direction of click movement. Words and the orthographic spaces between words were counted as units of measurement, with plus three being the constituent break and zero being either click position (a) or (c). Negative integers indicate units moving away from the break, while positive integers indicate units moving toward the break. For those rare occurrances where click locations might be made beyond the major constituent break, the distance from the actual click position will be computed using all positive integers. Thus if a click, objectively located in click position (c) were to be perceived by a subject as occurring in the word before the major constituent break (click position (b) and the +3 position) this location will be recorded as a +4 movement and then averaged as such with the subject's other seven click locations for sentences containing (c) click locations.

(a) (b) (c)

-4 -3 -2 -1 0 +1 +2 +3 +2 +1 0 -1 -2 -3 -4

The small scared girl - sat in the corner.

A number of four way ANOVAS were performed for all data, with levels of significance set at .05 or less (two tailed test). Again, the data for the Special Group was tabulated and scored exactly the same way, but not included in the statistical analysis for the experimental groups.

Results and Discussion

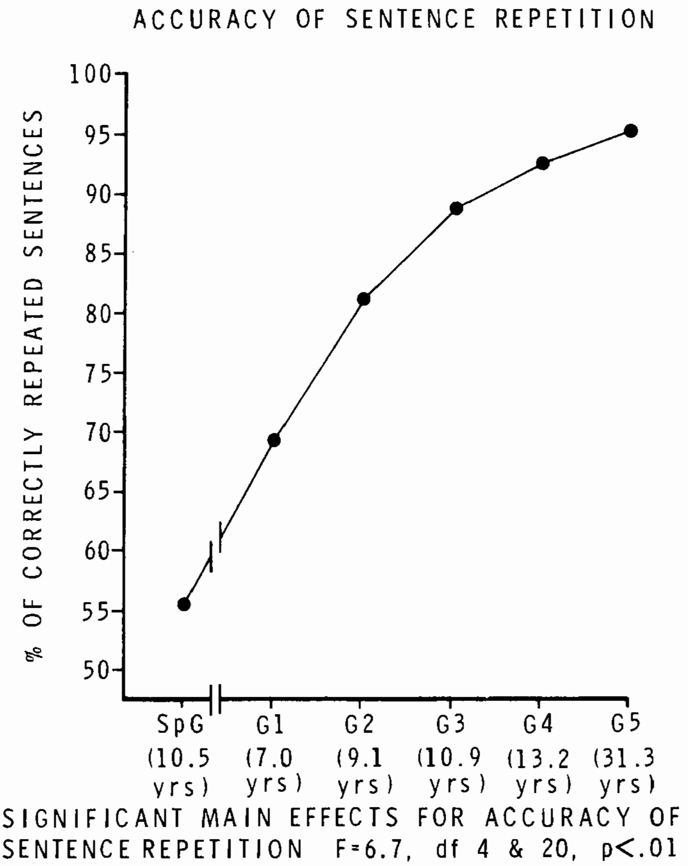
Accuracy of Sentence Repetition

The results of the three way ANOVA (Groups (5) x Sex (2) x Ear (2)) for accuracy of sentence repetition revealed only one significant main effect for groups ($F=6.75$, df 4 and 20, $p < .01$)supporting our hypothesis that accuracy of repetition improves with age. (See Figure 1.)

While our youngest Group (1) was able to accurately repeat almost 70% of the stimulus sentences, our Special Group subjects were only able to repeat back 55% of the sentences accurately enough to compute click locations and note click movement patterns. Although we did predict that this "memory" test portion of our experiment would improve with age, we had not anticipated that the improvement noted from group to group would be so regular. The important fact is that the 13 years old, Group 4, children essentially performed this repetition task as well as did the adults.

It is noteworthy that in all the analyses there was the lack of any significant main effects or interactions involving ear preference. While we had not anticipated any sex differences and found none, we had expected a possible ear advantage to come out of the analysis for at least some of our groups. Fodor and Bever (1965) originally found an ear advantage (i.e., the right ear click presentation resulted in more accurate click locations). Yet no ear effect of any kind or for any groups occurred in our study. Perhaps the relative simplicity and shortness of our stimulus sentences did not provide the level of difficulty necessary to elicit such ear effects reported by others.

Figure 1. Accuracy of Sentence Repetition. Special Group data is plotted but not calculated in statistical analysis for Groups 1 to 5.



Accuracy of Click Location

The results of the four way ANOVA for accuracy of click location revealed two significant main effects and one significant interaction.

1) There was a significant Group main effect ($F=4.97$, df 4 and 20, $p. < .01$) demonstrating that accuracy improved as age increased. (See Table 1.) This result also supports our major hypothesis.

2) There was a significant click position main effect ($F=14.77$, df 2 and 40, $p < .01$) indicating that clicks located in the major constituent break, click position (b), were accurately located (30.0%) significantly more often than clicks in either position (a) (22.7%) or (c) (5.8%). This was also true for the special group, but at a much lower percentage (see Table 1).

3) The significant interaction in this analysis was for groups x click location ($F=4.09$ df 8 and 40, $p < .01$). Notice in Table 1 that click position (b) does not have a strong effect on accuracy until Group 3 or around 11 years of age. There were no other significant main effects on interactions in this analysis.

As with the sentence repetition portion of the experiment, we expected that our older groups would be more accurate in their click locations and that click position (b) would be the most accurate click location across all groups. Indeed, our groups did become significantly more accurate ($p < .01$) in their click locations as age increased from a low of 9.7% accuracy in click locations for our youngest Group 1 to a high of 33% accuracy for

Table 1. Percent of Accuracy of Click Locations for Click Positions and by Individual groups.

GROUPS	CLICK POSITIONS A	CLICK POSITIONS B	CLICK POSITIONS C	MEAN % CORRECT PER GROUP
Special Group	2.3%	4.8%	0.0%	2.4%
Group 1	14.5%	12.1%	2.5%	9.7%
Group 2	39.6%	10.3%	7.4%	19.1%
Group 3	10.1%	30.7%	5.1%	15.3%
Group 4	7.5%	52.1%	1.6%	20.4%
Group 5	41.5%	45.1%	12.5%	33.3%
Mean % correct per click position	22.7	30.0	5.8	19.5% Grand mean % **accuracy**

our Adult group. Note however that the 13 year olds (Groups 4) were not as accurate as the adult Group 5 in this portion of the click location experiment (20% vs 33% accuracy). This indicates to us that even these older children may not have the same level of perceptual proficiency possessed by adults.

We also did find a striking similarity when we compared the general accuracy level of our experimental groups (30%) to the accuracy level obtained by adults in the Seitz and Weber (1974) study (29%) where twelve word sentences of a more complex construction were used as stimulus sentences. It is possible that the higher level of accuracy for our Adult group (33%) may be the result of a reduction in length and complexity of the stimulus sentences used.

It is interesting to note that there was quite a shift in accuracy of click locations between the groups which is reflected in the significant group by click position interaction ($p < .01$). Table 1 reveals that the in-break click position (b) is not the most accurately located click position until the subjects are around 11 years old (Group 3). The two younger groups are actually more accurate in the (a) click position. Note also that our special group had great difficulty in locating any of the clicks accurately in any position.

One could conclude that this change in accuracy of click locations might reflect changes in the development of perceptual processing skills in our subjects. If so, the exact nature of the development is not clear from the present experiment. One could speculate that the differences in click location accuracy might be reflective of a child's shift in cognitive processing from the concrete operational stage to a more formal operational stage with an accompanying shift in more abstract rule application to perceptual strategies. This is an exciting possibility, but such a speculation must be made cautiously because of the relatively limited sample size of the present study and the need for further study.

One other possibility exists to account for at least some of the lack of the click position accuracy in our youngest groups. Many of the younger subjects located the (b) clicks on the word just prior to its actual occurrance, thus making an error. It appears that these younger subjects might not have truly understood our instructions concerning the possibility of the click occurring between words as well as simultaneously with words, or else these younger subjects were unable to perceive the click as occurring between words.

Click Migration Effects

As with the previous analysis, there were the two expected main effects and one interaction resulting from the ANOVA for click migration effects. There was the anticipated significant main effect for groups ($F=5.08$, df 4 and 20 $p < .01$) with all groups showing mean movement* toward the major constituent break.

There was also a significant main effect for click positions ($F=18.92$, df 1 and 20 $p < .01$) indicating that there was much more movement toward the break from the post break click position (c) (2.59 units) than pre-break click position (a) (1.02 units).

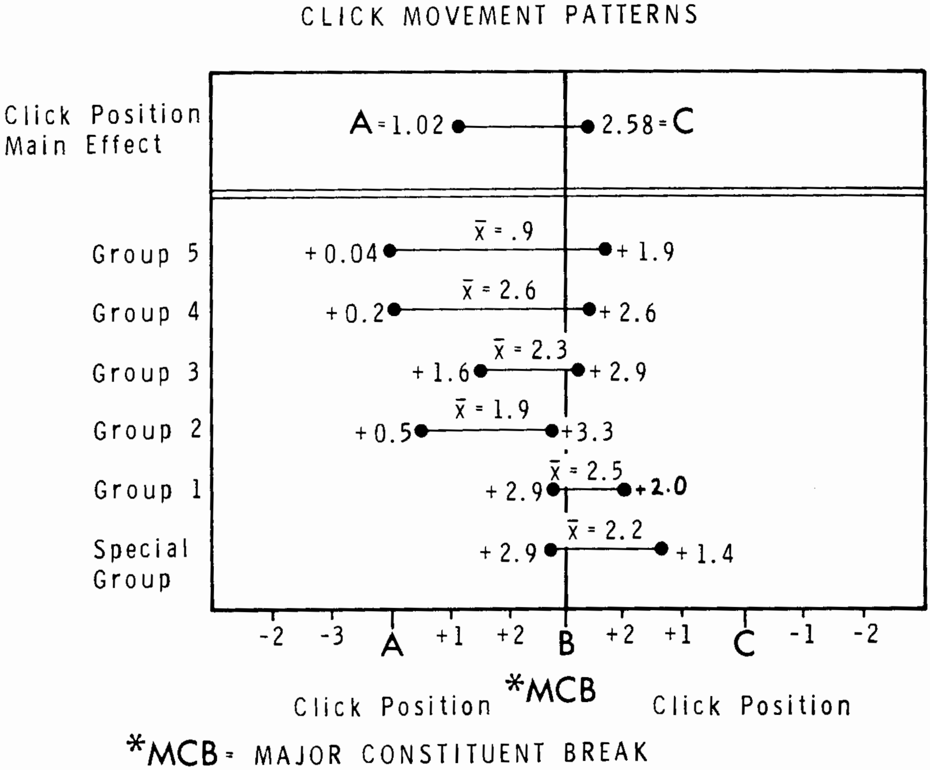
The significant interaction was group by click position ($F=3.32$, df 4 and 20 $p < .05$) clarifying the click position difference by individual group.

The group plots displayed in Figure 2 clearly show that positive click displacement toward the major syntactic break did in fact occur for all the experimental groups as well as the Special Group. However, this movement toward the break varied significantly ($p < .01$) between click position (a) and (c) as a significant interaction between click positions and groups ($p < .05$). There was definitely more movement toward the break from click position (c) that from click position (a) for Groups 2, 3, 4 and 5, but not for our Special Group or our

* Mean movement reflects the average amount of computed movement from both the (a) and (c) click positions.

youngest Group 1. Both these later groups, it appears, located the clicks later in the sentence perhaps as a result of some form of recency strategy. That is, these two groups may have made remembering the sentence more important, and, then located the click, as an after-thought, on one of the words occurring toward the end of the stimulus sentences. Thus, the major constituent break did not affect the Special Group and Group 1 click location patterns in the same manner as the older groups.

Figure 2. Plot of Click Movement for Click Positions and by Group.



While all groups demonstrated some movement toward the break, the older groups showed progressively less movement from the (a) click position and our adult Group 5 showed an additional reduction in movement from click position (c). Although, there appears to be a progressive reduction in click movement reflected in these data, the over-all movement means are actually larger than those found by Seitz and Weber (1974), using more complex sentences. In addition, in the present study click movements demonstrated a stronger (a) click position movement (a= +1.02 units) than the Seitz and Weber study (a=-.71). Obviously the major constituent break had a drawing effect in this experiment. This conclusion is warranted by the simple fact that clicks in the (a) position did move, however little, toward the major constituent break but rarely, if ever, through this break. The only subjects that located clicks from the (a) position through the major constituent break toward the (c) position were our Special Group children and, in one instance, a child in our youngest Group 1. For all the rest of our Groups the major constituent break acted almost like a natural barrier. This barrier effect was not as strong, however, for clicks located in position (c) as it was for clicks in position (a). Many of our experimental subjects located a few clicks from click position (c) beyond the major constituent break toward the (a) side of that break. (See Group 2, Figure 2 for example). Yet rarely (only two occurrences) did these "overshoots" from click position (c) go beyond the first word on the (a) side of the break.

Because of this limited movement it cannot be said with certainty that these locations were truly overshoots. One must remember that while the major constituent breaks in our sentences occurred linguistically between two words, the sentences themselves were recorded in such a manner as to minimize pauses or pitch inflections around the major sentence breaks. In addition, our data indicated that the two younger groups tended to always pick on words to locate the superimposed click. Only our older groups indicated that the clicks might have occurred between two words. Indeed, it is a weakness of our present study that we did not foresee this possibility with our youngest subjects. If we take into consideration that the younger children may not have clearly understood our response requirements, then our data could support the contention that the major constituent breaks in our sentences strongly attracted click locations for our groups.

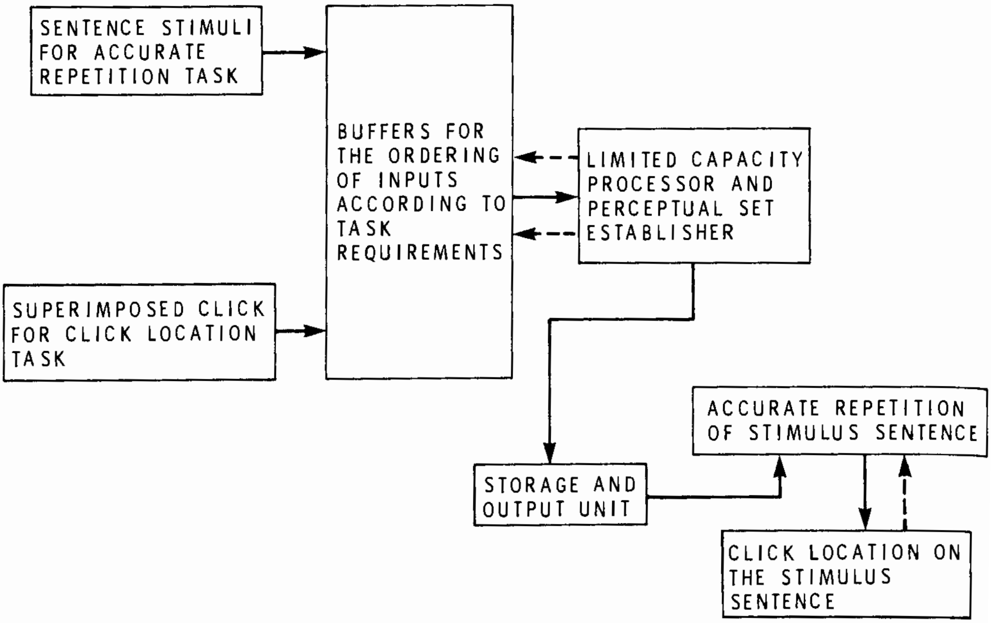
The question of why the difference in click location patterns did occur arises. Olson and Clark (1976) have provided a general scheme that we have modified to outline the perceptual processes that might occur under the experimental design we have used. (See Figure 3). In this scheme, there are two internal events that must work together to accomplish the click location task; the buffers for ordering inputs (i.e. which stimulus requirement should have precedent, the click location or sentence memory), and the limited capacity processor (i.e. actual short term memory capability and perhaps linguistic rule processing). The ability for our subject to get both these more cognitive activities together seems to be a function of their linguistic age and mental maturity. The variability in click locations given by our groups seems to support this speculation. For example, all our Special Groups and youngest Group 1 subjects were able to handle was the required memory task. It is possible that they concentrated all their energies on getting the sentence correct. Only then did they give thought to the click location task. Perhaps Titchener's (1909) "law of prior entry" can be utilized to support our contention that for these two groups, the sentence became the primary stimulus to be perceived, while the click became the other accompanying stimulus.

It appears then that as children mature and obtain a better grasp of their innate linguistic rules and expand their short term memory, they become better able to selectively emphasize the presence of either the superimposed click or the stimulus sentence. There are two possible explanations for this improvement: a) as they develop the children's short term memory abilities expand; and b) as they mature children gain more understanding and knowledge of syntax, thus allowing them to break the stimulus sentences into noun-phrase/verb-phrase segments. It is also possible that both these processes happen together. That is, as the children's syntactic ability improves, they are better able to perceive sentences in noun-phrase/verb-phrase segments, thereby producing a more efficient means to store these sentences in their short term memory. If any or all of these potential explanations are valid, then the easiest click to locate should be the one that occurs in the major constituent break (position b in this study) because it occurs at a time in perceptual processing that least interferes with sentence memory. Our data on accuracy of click locations offer support for this speculation (see Table 1).

How powerful a draw the major constituent break has in click location experiments is most likely a function of many complicated and interdependent aspects. Some of these are: the overall length and/or complexity of the stimulus material, the actual syntactic structure of

Figure 3. Schema for Perceptual Processes Used in Click Location Experiments.

SCHEMA FOR POSSIBLE PERCEPTUAL PROCESSES USED IN THE CLICK LOCATION TASK



the stimulus sentences, (i.e. the relationship between surface and deep structure constituent breaks), the presence or absence of normal speech intonation, pitch, stress and pause patterns, and the experimental response requirements themselves. While some of these variables have already been explored, all need more research if we are ever going to be able to separate the competence component from the limitations and realities of the performance data.

Summary and Conclusions

This study investigated changes in click location patterns as a function of maturation. Five experimental groups and a language delayed group were all given the same click location task to perform. We hypothesized that the ability to perform the click location task would improve as a subject matured. This general hypothesis was confirmed. Specifically, we found that:

1. Subjects' ability to accurately repeat the stimulus sentences improved with age.
2. Subjects' accuracy in click location improved with age.
3. Click migration patterns varied as a function of age, with a tendency toward restriction of the click migration patterns being observed in the older groups.

In addition, one other item seems clear to us, while the Special Group subjects were not very successful in some of the experimental tasks, the click location technique can be used successfully with language delayed children. What must be done, however, is to reconstruct the stimulus material to better fit their capabilities, i.e., reduce the sentence length and more carefully control the sentence complexity. In addition, analysis of both the correct and incorrect sentences would reveal much more about the level of perceptual and linguistic abilities of these special children than the present study did. This is now being done in our lab.

Acknowledgements

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Appendix A: Stimulus Sentences

1. ((All of) (the) (good) (guys)) + ((played) (it) (safe))
2. ((That) (small) (girl)) + ((is) ((our) (now) (music) (teacher)))
3. ((The) (tall) (handsome) (young) (prince)) + ((took) ((a) (wife)))
4. ((All) (my) (friend)) + (((saw) (me)) ((in) ((the) (ballet))))
5. ((Someone) ((with) ((a) (big) (nose)))) + ((chased) (me) (home))
6. ((That) (cute) (little) (black) (dog)) + ((is) (not) (mine))
7. ((The) (nice) (new) (girl)) + (was) ((sick) (last week))
8. ((My) (old) (torn) (shirt)) + ((is) ((in) ((the) (wash))))
9. ((The) (lonely) (old) (man)) + ((cried) (all night long))
10. ((It) ((rained) (all day))) + (so) ((we) ((stayed) (home)))
11. ((The) (ugly) (mean) (old) (witch)) + ((rode) ((her) (broom)))
12. ((My) (great) (aunt)) + ((stopped) ((to eat) ((her) (dinner))))
13. ((Your) (new) (gray) (cat)) + ((ripped up) ((your) (book)))
14. ((Sue) and (Bob)) + (((went) (home)) ((after) ((the) (game))))
15. ((John) ((ran) (fast))) + (but) ((we all) ((caught) (him)))
16. (((The) (star)) ((of) (my team))) + ((scored) ((two) (goals)))
17. ((The) (small) (scared) (girl)) + ((sat) ((in) ((the) (corner))))
18. ((My) (friend) (Jane)) + (((called) (me)) ((on) ((the) (telephone))))
19. ((Tom) and (Ann)) + (((took) (me)) ((to) ((their) (home))))
20. ((Tommy) ((chased) ((his) (dog)))) + (but) ((he) (ran away))
21. ((The) (school) (track) (team)) + ((won) ((six) (running) (contests)))
22. (((The) (boy)) and ((his) (friends))) + ((played) ((with) (trains)))
23. ((He) (stood up)) + (and) (((his) (book)) (fell down))
24. (((My) (baby) (sister)) ((went) (home))) + (and) ((I) (stayed))

+ indicates major constituent break

() indicate surface phrase structures

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