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Chapter 14

GESTURE MIRRORS SPEECH MOTOR CONTROL IN STUTTERERS

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The relationship of stuttered disfluency to manual gesture during spontaneous speech was investigated in three studies. In the first study, adult stutterers produced fewer narrative details with simpler sentence structures compared to fluent controls matched for age and sex. Similarly, their speech was accompanied by fewer gestures and these gestures were simpler in form and meaning than those of the controls. Stuttered disfluencies were negatively correlated with the frequency and complexity of gesture; no such relationship was observed for normal disfluencies. The second study demonstrated that these effects are not caused by a motor-shutdown of hand and arm movement during stuttering. The third study investigated these effects in children. Like adults, children who stuttered accompanied significantly less of their spontaneous speech with gesture than controls matched for age and sex. We interpret these results to mean that the gesture-to-speech ratio during spontaneous expression reflects linguistic processing capacity.

INTRODUCTION

Are gesture and speech linked together in spontaneous expression? In order to shed light on this complex question, we have been investigating the gesture-speech relationship in adults and children who stutter. Before describing our work, it is important that we contextualize it by briefly summarizing current work in this area.

There are two competing theories as to how gesture and speech are related during the act of spontaneous, linguistic expression. The traditional and most commonly held hypothesis is that gesture and speech are autonomous and separate communication systems (Butterworth & Beattie, 1978; Butterworth & Hadar, 1989). In the *compensatory* framework, gesture functions as an backup or auxiliary system for the temporary absence or failure of speech, such as in coughing, having a mouth full of food, or being unable to put words to thoughts. Note that this hypothesis requires speech to fail in order for gesture to appear in the speech stream. The compensatory explanation of how gesture and speech are related predicts that stuttered speech will be accompanied by more gestures than will fluent speech.

An alternative hypothesis is that gesture and speech work together to form an integrated system for the single purpose of linguistic expression (Kendon, 1980; McNeill, 1985, 1992). In the *integrated system* framework, gesture is linked to the structure, meaning, and timing

of spoken language. Thus, speech and gesture will always be co-expressed. The integrated system hypothesis predicts that stuttered speech will be accompanied by fewer gestures than fluent speech.

It is important to know that gesture occurs primarily during the act of speaking spontaneously and much less frequently, or rarely, in rehearsed, memorized, or read language (Krauss, 1996). This may be because, as McNeill (1992) has postulated, gesture is the product of putting thoughts to sentences and not simply uttering speech without meaning.

It is also important to note that by the term gesture we are referring specifically to the non-purposive movements of the hands and arms that accompany spontaneous speech. We are not referring to the more global concept used in stuttering research of what is commonly called *nonspeech behavior* where bodily actions, such as head and eye movement and lip, have been observed and documented to co-occur with and become incorporated into the stuttered disfluencies of children (Conture & Kelly, 1991; Schwartz et al., 1990).

Recent research has shown that gesture is linked to the structure of language in many ways. For example, American speakers typically produce 80 to 90% of their gestures simultaneously with speech at a rate of approximately 1.5 gestures per minute. Kendon (1980) and McNeill (1992) have observed that three different kinds of gesture are used to mark discourse structure across languages. These kind of gestures are *deitics*, or points at either real or abstract locations, *beats*, or up and down movements of the hand that are void of meaning, and *representational gestures*, which are gestures that depict, either concretely and abstractly, actions, people and objects, and spatial relationships. The meaning of the gesture that co-occurs with speech is either redundant with or supplementary to the meaning expressed in spoken language.

Data on the timing of gesture and speech production are limited, but Nobe (1996) has recently found that English speakers produce the stroke, or central and salient, movement of representational gestures such that it coincides with the peak stress of the phrase being spoken. Although the peak of the gesture movement and the peak phrasal stress are co-produced, the hand can be observed to prepare to gesture well before the particular phrase begins, sometimes in the silent pauses between clauses.

Thus, stuttering provides us with an opportunity to investigate the nature of the gesture-speech relationship when speech production is disrupted by stuttered disfluency. The question is whether gesture will show comparable disruptions, as the integrated-systems hypothesis predicts, or whether gesture will increase in frequency to compensate for disruptions in speech production caused by stuttered disfluency, as the compensation hypothesis predicts.

STUDY I

The goal of our first study was to analyze and describe the gesture-speech relationship in disfluent as compared to fluent speech in order to test these two hypotheses about the nature of the gesture-speech relationship (Mayberry et al., 1996; Scoble, 1993; Shenker et al., 1995). We used a 'cartoon narration task' to elicit spontaneous speech from subjects who identified themselves as stutters along with matched control subjects.

Study 1 Methods

Each subject was tested individually and watched a 7 minute animated cartoon. After watching the cartoon, the subject narrated the story line to an unfamiliar listener. The listener made few comments other than, "anything else," and never gestured. We videotaped the subject's narration and then began the time-consuming task of transcribing and coding it. The transcription and coding consisted of three steps. First, the gestures were transcribed without the sound track. We noted the location and kind of gestures and along with their probable meanings. Next the speech was transcribed verbatim without the video picture and all speech disfluencies were noted and described. Third, the two transcripts were assembled by noting which gestures co-occurred with which words, clauses, and speech disfluencies. Although the transcriptions were done by hand, the actual counting and tabulating was computerized (Miller & Chapman, 1984).

Study 1 Subjects

The subjects were 12 English speaking adults. Six subjects identified themselves as stutterers, five males and one female ranging in age 21 to 51 years. Their stuttering severity according to the Iowa Scale was mild for two subjects, moderate for two, and severe for two (Johnson & Darley, 1963). We matched the subjects by age, sex, and level of education to 6 control subjects with no history of stuttering[1].

Study 1 Results and Discussion

The subjects who stuttered tended to say less using simpler sentence structure in more time than the controls. This was true for number of words, clauses, embedings and narrative details. Although the greatest difference between the groups was in the number of stuttered details. Although the greatest difference between the groups was in the number of stuttered disfluencies produced, there were no differences in the number of normal disfluencies produced.

The subjects who stuttered produced significantly fewer total gestures than the controls. However, gesture production was not a simple function of how much the subjects talked. The ratio of gesture to speech was significantly different for the two groups. The controls accompanied 84% of their words with gesture and gestured 68% of the total time they spoke. By contrast, the subjects who stuttered accompanied only 34% of their words with gesture and gestured for only 23% of the total time they spoke.

These findings clearly support the *integrated system* hypothesis. Gesture production is highly associated with the fluent expression of spoken language and not with speech breakdown as the *compensatory* hypothesis predicts. This is further demonstrated by the high and positive correlations between the structure and content of the subjects' speech and the structure and content of their gesture. The number of words and clauses spoken were highly and positively correlated to the number of gestures produced [$r = +0.53$ (df=11, $p<.05$) and $r=+0.94$ (df=11, $p<.01$)]. Moreover, the number of narrative details given in the spoken discourse was highly correlated with the meaning complexity of the gestures [$r=+0.62$ (df=11, $p<.05$)]. Finally, the number of gestures produced while speaking was positively correlated with normal speech disfluencies [$r=.57$, $p<.05$] but negatively correlated with stuttered disfluencies [$r=-.31$, n.s.].

The dependency of gesture production upon fluent speech production is clearly shown by an analysis of normal as compared to stuttered disfluencies. By stuttered disfluencies we mean disfluencies that fragment word production, such as sound and syllable repetitions and prolongations. By normal disfluencies we mean word and phrase repetitions that do not fragment word production. Both groups produced gesture simultaneously with normal speech disfluencies with equal frequency. Importantly, however, gesture was rarely co-produced with stuttered disfluencies, as Figure 1 shows. In those rare instances when a gesture was co-produced with a stuttered disfluency, the gesturing hand could be readily observed to fall to rest during the moment of stuttering and then to rise again and resume the gesture within milliseconds of the resumption of fluency. Less frequently, the gesturing hand would stop moving during the moment of stuttering and resume moving within milliseconds of speech fluency resumption.

These results provide striking evidence of how gesture and speech are fundamentally and deeply linked for the single purpose of linguistic expression. The structure and content of gesture mirrors the structural and semantic properties of the co-expressed spoken language. This mirroring is also evident in the tight temporal relationship between the two. Smith and her colleagues (Franz et al., 1992; Smith et al., 1986) have shown that cyclic movements of the mouth and arm and fingers harmonize with one other in motor repetition tasks and that speech amplitude correlates with finger movement. Our findings show that the synchronization of dynamic gesture and speech motor patterns during spontaneous language production are all ultimately coordinated with the single linguistic meaning being expressed simultaneously by both modes (Tuite, 1993).

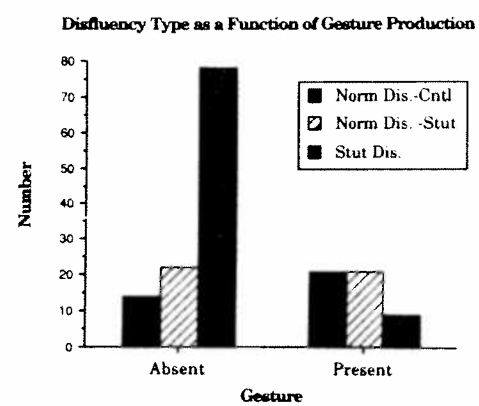

Figure 1. Gesture production accompanies the normal disfluencies of subjects who stutter and fluent controls with equal frequency. By contrast, gesture production seldom accompanies stuttered disfluencies.

Stuttered disfluency never disrupts this co-expression principle.

STUDY II

In order to rule out out a purely motor-shutdown explanation for this phenomenon, we asked three subjects who participated in the first study to participate in a second one where they narrated a second cartoon under three dual-task conditions. In the first dual task, the subject narrated a cartoon and simultaneously pressed a button continually. In the second dual task, the subject pressed a button to signal that he or she was stuttering. And in the third task, the subject took a pencil and wrote the word being stuttered. The subjects were able to carry out the simultaneous hand and speaking tasks without any disruption to their manual motor patterns during moments of stuttering. These findings demonstrate that stuttered disfluency, per se, does not impede hand and arm movement. Thus, the effects of stuttered disfluency on manual gesture cannot be explained by a simple manual-motor-shutdown explanation.

This means that gesture production is attenuated and/or interrupted by stuttered disfluency, not because the hand is unable to move, but because gesture expression is always concordant with speech expression. Gesture-speech concordance is evident in the coordination of structure, meaning, and motor execution timing. If gesture expression were to continue while speech was disfluent, the result would be a temporal asynchrony and semantic anomaly between gesture and speech. Such asynchronous anomalies never occurred in any of our three data sets.

STUDY III

In the third study, we replicated the results of the first study with two pairs of preadolescent boys who were 11 years old (DeDe, 1996). Two subjects were rated as showing a severe level of stuttering and two control subjects were matched by age, sex, and handedness.

The gesture-speech expression of the child subjects paralleled that of the adult subjects except that both pairs of children did not gesture as frequently as did the adults. However, the control children produced many more total gestures than did the children who stuttered at a ratio of nearly 3:1. The control children accompanied 26% of their words with gesture while the children who stuttered accompanied only 8% of their words with gesture. Again, the attenuated gesture production of the children who stuttered was accompanied by attenuated expression of spoken language. This was evident in terms of fewer words and clauses and simpler sentence structures. Like the adults who stuttered, the children who stuttered never used gesture to compensate for stuttered disfluencies. Also like the adults, the children primarily co-expressed gesture with fluent speech and normal disfluencies and almost never with stuttered disfluencies.

Comparing the gesture-speech ratios of the adults with those of the children reveals a very clear trend in the developmental relationship of gesture to speech, as Figure 2 shows.

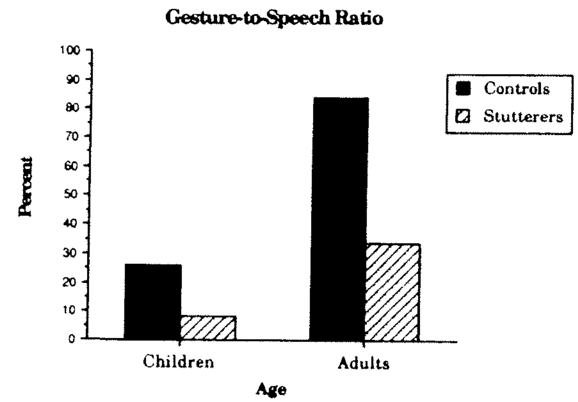

Figure 2. The amount of speech (measured in total number of words) that is accompanied by manual gesture (measured in total gestures) increases dramatically between the ages of 11 and adulthood and, moreover, is highly attenuated by stuttering in both children and adults.

The gesture-to-speech ratio increases four-fold between preadolescence and adulthood. This is true for both the controls and the subjects who stutter.

This developmental trend suggests to us that gesture production is constrained by the overall capacity to process language. Although 11-year olds have acquired nearly all of their grammar and have a very large lexicon, their capacity to process language is nevertheless limited in comparison to that of adults. At the same time, their gesture-to-speech ratio is four times less than that of adults. We interpret these substantial differences in the gesture-to-speech ratio to reflect the greater capacity of adults to process language than preadolescents. In other words, we propose that increases in linguistic processing capacity are marked by concomitant increases in the gesture-to-speech ratio during the act of spontaneous language expression.

GENERAL DISCUSSION

The results of these studies lead directly to the question of why stuttered disfluency so dramatically attenuates the gesture-to-speech ratio in the spontaneous language production of adults as well as children. Our working hypothesis is that the gesture-to-speech ratio is a reliable and valid indicator of language processing capacity. This explanation means that that gesture decreases with increases in stuttered disfluency because stuttering drains linguistic processing resources.

In our proposed framework, the frequency and duration with which gesture appears in the speech stream may indicate how much mental processing space and processing resources are being used to produce the spoken portion of the linguistic message. When the spoken portion of the message absorbs most of the available processing capacity, few resources remain for the gestural portion of the linguistic message to be expressed. This would mean that the spoken portion of the message has priority on linguistic processing resources while the gestured portion of the message gets any processing resources that remain.

In conclusion, our findings demonstrate clearly that the relationship of gesture to speech is a highly principled one of integrated co-expression of a single linguistic message. Because gesture production is characteristic of fluent (and we hypothesize 'easy') speech and not of disfluent (or 'difficult') speech, we believe that it provides a potentially powerful and meaningful new tool with which the disorder of stuttering can be observed, evaluated, and potentially, treated.

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NOTE

1 Subjects were unpaid volunteers. The experimental protocol of this study was approved by the Ethics Committee of the School of Communication Sciences & Disorders of McGill University.

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