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Creating a New Communication System: Gesture has the Upper Hand

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Abstract

How does modality affect our ability to create a new communication system? This paper describes two experiments that address this question, and extend prior related findings by drawing from a significantly more extensive list of concepts (over 1000) than has been used previously. In Experiment 1, participants communicated concepts to a partner using either gestures or non-linguistic vocalizations (sounds that are not words). Experiment 1 confirmed that participants who gesture 1) produce more strongly 'motivated' signs that physically resemble the concepts they represent (i.e., are iconic), 2) are better able to correctly guess the meaning of a partner's signs, and 3) show stronger alignment on a shared inventory of signs. Experiment 2 addressed a limitation of Experiment 1 (concurrent feedback only in the gesture condition). In Experiment 2 concurrent feedback was eliminated from the gesture and vocal conditions. Gesture again outperformed vocalization on communication effectiveness and sign alignment.

Keywords: Alignment; Gesture; Vocalization; Multimodal; Motivated; Signs; Language Origin; Embodied Cognition

Introduction

*'What's in a name? That which we call a rose
By any other name would smell as sweet'*

William Shakespeare (trans. 1914. 2.2. 47-48)

Most of the words we use to communicate are arbitrarily associated with their referents (Saussure, 1959). As Shakespeare observed, the word 'rose' conveys its meaning through learned convention, without which, that particular combination of phonemes would be meaningless. How then, do words acquire their meaning, and how did Homo sapiens bootstrap the complex communication systems that make our species so unique and successful?

Several competing theories of language origin have been proposed. The proto-speech account (e.g., Cheney & Seyfarth, 2005) suggests that language evolved out of rudimentary vocalizations that acquired communicative meaning over time, while the proto-sign account argues that

language evolved first from manual gestures, before shifting to the vocal modality (Corballis, 2003; Arbib, 2005).

Because modern humans already possess complex, shared language systems, we are unable to experimentally replicate the context in which language arose. However, comparing communication in the vocal and gestural modalities allows us to make inferences about the characteristics of human communication that equipped our ancestors to develop complex sign systems. Fay, Lister, Ellison and Goldin-Meadow (2014) compared the communicative affordances of gesture and vocalization through a referential communication task in which participants were prohibited from using their shared language. Participants communicated a set of 18 recurring concepts to a partner, either through gestures-only, non-linguistic vocalizations-only, or a combination of both. In line with the proto-sign account, participants who gestured were more successful at communicating meanings to their partner than the participants who were restricted to the vocal modality. Participants who gestured were also more likely to reproduce the signs that their partner had previously used when communicating the same concepts. This process, known as interactive alignment (Pickering & Garrod, 2004), underlies the development of a shared inventory of signs. Sign alignment was also positively related to participants' communication success. Fay et al. (2014) suggested that gesture was a more successful mode of communication compared to vocalization because it more naturally lends itself to the production of 'motivated' signs (i.e. iconic or indexical signs that share a direct, or non-arbitrary, relationship with their referent). While the authors did not directly examine sign motivation, they suggested that participants who gestured were better able to physically represent the concepts they wished to communicate (e.g., through mimicry or pantomime).

Studies such as these indicate a critical role for gesture in communication. Theories of embodied cognition and gesture as simulated action (e.g., Hostetter & Alibali, 2008) suggest that our language and motor pathways are intimately connected, both neurally and behaviourally.

However, recent studies have shown that participants are also able to produce motivated vocalizations (Perlman, Dale, & Lupyán, 2014). Perlman et al. (2014) demonstrated that, like gestures, motivated vocalizations can convey meaningful information, and may also be capable of bootstrapping human language.

These studies, like other referential communication studies, are limited by the small number of concepts used. In most referential communication tasks, participants communicate the same 20 concepts (or fewer) to a partner (e.g., Garrod, Fay, Lee, Oberlander & MacLeod, 2007; Fay, Arbib and Garrod, 2013; Perlman et al., 2014; Fay et al., 2014). Thus, current knowledge about the emergence of human sign systems is limited to a small number of experimenter-selected concepts. Experiment 1 addresses this issue.

Experiment 1

Experiment 1 extends the Fay et al (2013, 2014) referential communication studies by dramatically increasing the range of concepts participants communicate. Instead of presenting all participants with the same set of 18 recurring concepts, the present study samples without replacement from a set of 1000 of the most common adjectives, nouns and verbs in the English language (from the Corpus of Contemporary American English; Davies, 2008). This is the first referential communication study to sample from such an extensive range of concepts, reducing the likelihood that any findings are an artifact of a specific stimuli set.

Perlman et al. (2014) demonstrated that it is possible to produce motivated signs through non-linguistic vocalization, suggesting that the gesture modality is not unique in its affordance of motivated signs. Our experiment extends this work by providing a direct comparison between the vocal and gestural modalities (as the authors explored the vocal modality alone). Experiment 1 includes a gesture-only and vocal-only condition. While Fay et al. (2013, 2014) speculated that gesture outperformed vocalization owing to its affordance of motivated signs, they did not examine sign motivation. Experiment 1 compares sign motivation in the different modalities by having coders rate each sign produced in each modality in terms of the degree of sign motivation (ionic to arbitrary).

Pairs of participants communicated a range of different concepts (Adjectives, Nouns, Verbs) to a partner in each communication modality (Gesture-only, Vocal-only). Participants communicated the same concepts repeatedly, over 6 games. From game to game, participants alternated roles between Directing (i.e. attempting to communicate their list of words to their partner), and Matching (i.e. trying to guess what words their partner was communicating). By alternating roles across games, the participants were able to copy (or not) features of their partner's signs. Participants' signs were then rated in terms of degree of sign motivation, and the extent to which they copied, or aligned with, their partner's previously produced sign for the same meaning.

In line with the speculations made by Fay et al. (2014), Hypothesis 1 is that sign motivation will be higher for signs produced in the gesture-only condition than in the vocal-

only condition. Hypothesis 2 is that communication success will be higher for gesture than for non-linguistic vocalization. Hypothesis 3 is that sign alignment will be higher in the gesture-only condition than in the vocal-only condition.

Method

All participants viewed an information sheet before giving written consent to take part in Experiment 1. Information sheets and consent forms were approved by the University of Western Australia Ethics Committee.

Participants One hundred and six undergraduate students (sixty-three females) participated in exchange for partial course credit. Participants were placed into unacquainted pairs, and completed the testing session in approximately one hour. All were free from auditory, visual, speech and motor impairments.

Materials Participants tried to communicate (in pairs) a set of 18 target concepts. The concepts were sampled without replacement from 1000 of the most frequently used words in American English (from the Corpus of Contemporary American English; Davies, 2008), and fell equally into three categories: adjectives, nouns and verbs. Participants were also presented with six distractor concepts that were never communicated. A different item set was communicated by each pair.

Task and Procedure Participants completed two referential communication tasks (gesture-only and vocal-only). Each task was comprised of six separate games. During each game, one participant (the Director) would communicate their list of 18 recurring concepts to their partner (the Matcher). At the end of each game, participants would swap roles, so that the participant who had acted as Director would become the Matcher for the next game, and the Matcher would become the Director.

Each pair of participants communicated a different set of concepts in the gesture-only and vocal-only modalities. Communication modality was counterbalanced across participants. In the gesture-only condition participants were seated facing one another, and were only allowed to communicate through gesture (i.e., movements of the hand, body and face). In the vocal-only condition participants were seated facing away from each other to eliminate the possibility that they might communicate through gesture. Participants in this condition communicated through non-linguistic vocalizations (i.e., sounds that are not words, and are made with the body or vocal chords).

iPads were used to run the experiment. During each game, the to-be-communicated concepts would appear sequentially on the Director's iPad. The Matcher's screen would display all 18 target concepts, plus 6 distractor concepts, for the duration of the game. Matchers would try to guess which concept the Director was communicating, and would select that concept using their touch screen. Following the Matcher's selection, the next to-be-communicated concept would appear on the Director's screen. Matchers were allowed to select the same concept more than once within

the same game, however every concept was only presented to the director once in each game. Directors were allowed to produce as many gestures or vocalizations as they wished for each concept. Once all 18 concepts had been communicated, that game would end, participants would swap directing/matching roles, and begin the next game.

Results and Discussion

Sign motivation, Communication success and sign alignment were measured.

Motivation Sign motivation was quantified using a 7-point likert scale. Here, a rating of 0 indicates that the sign is entirely symbolic and bears no physical resemblance to the concept being communicated. A rating of 6 indicates that the sign is highly motivated, and is either an icon or an index of the concept being communicated. When directors produced multiple gestural or vocal signs for a concept, the motivation of each distinct sign was rated separately. These ratings were then used to calculate a mean motivation score for each concept, at each game.

One coder (CJL) coded all signs for sign motivation. Signs produced by 12 participant pairs were coded for sign motivation by a second coder who was naïve to the experimental hypotheses. This gave 2592 separate observations (~20% of the data). Intraclass correlations demonstrated high reliability between the coders for signs in the Gesture-only (82%) and Vocal-only (89%) conditions ($p < .001$).

Hypothesis 1 was that sign motivation would be higher for gestured signs than for signs produced using non-linguistic vocalization. For analysis, we took averages of the sign motivation ratings at each game, across each category of concept (Adjective, Noun, Verb). The data was entered into a three-way repeated measures ANOVA that treated Modality (Gestural, Vocal), Game (1-6) and Concept (Adjective, Noun, Verb) as within-participants factors. This returned a significant main effect of Condition, $F(1, 52) = 700.33, p < .001$, confirming that participants who gestured produced more motivated signs than those who vocalized; and Game, $F(5, 260) = 39.89, p < .001$, reflecting an increase in sign motivation across games 1-6 in both conditions. There was also a main effect of Concept, $F(2, 104) = 5.73, p = .004$, with pairwise comparisons showing participants' signs for verbs and nouns to be significantly more motivated than those they produced for adjectives, $p < .05$. There was no difference between the motivation of verbs and nouns, $p > .05$. Finally, there was also a significant interaction between Game and Condition, $F(5, 260) = 3.64, p = .003$. To explore the interaction, one-way repeated measures ANOVAs were conducted upon each condition. These confirmed that motivation scores increased across games 1-6 in both the Gesture and Vocalization conditions. Difference scores between each condition were calculated at game 1 and game 6. A paired samples t-test revealed a greater difference in sign motivation between conditions at game 1 ($M = 2.99, SD = .84$) compared to game 6 ($M = 2.77, SD = .86$), $t(52) = 2.17, p = .04, d = .60$.

Communication Success Communication success was assessed in terms of 'identification accuracy'; the percentage of correct guesses made by the matcher within each game and across each concept category (Adjective, Noun, Verb). Hypothesis 2 was that communication success would be higher for gesture than for non-linguistic motivation. As Figure 1 shows, participants' identification accuracy increased across games 1-6 in both conditions and across all concept categories. Across all games communication success was higher in the gesture-only condition than in the vocal-only condition. The different concept types were communicated equally well.

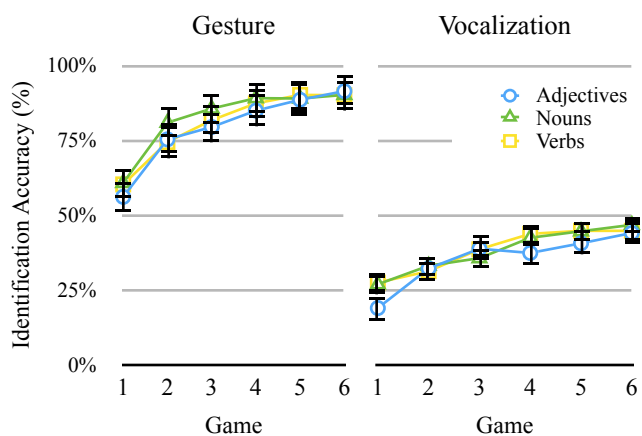


Figure 1: Participants' communication success across games 1-6 in the Gestural and Vocal modalities.

A three-way, repeated measures ANOVA that treated Modality (Gestural, Vocal), Game (1-6) and Concept (Adjective, Noun, Verb) as within-participants factors confirmed these observations. There was a significant main effect of Condition, $F(1, 52) = 591.95, p < .001$, confirming that participants who gestured outperformed those who vocalized; a significant main effect of Game, $F(5, 260) = 95.63, p < .001$, reflecting improvement in identification accuracy across games in both conditions; and a significant interaction between Game and Condition, $F(5, 260) = 3.47, p = .005$. There was no main effect of Concept, $F(2, 104) = 1.10, p > .05$.

To examine the nature of the interaction, one way repeated measures ANOVAs were conducted upon each condition. These confirmed that identification accuracy increased across games 1-6 in both conditions. Difference scores between each condition were calculated at game 1 and at game 6. A paired samples t-test confirmed that there was a greater difference in identification accuracy between conditions at game 6 ($M = .45, SD = .18$) compared to game 1 ($M = .37, SD = .17$), $t(52) = -2.29, p = .03, d = .64$. This reflects a greater rate of increase in identification accuracy in the Gesture condition across games 1-6 compared to the Vocal condition.

Alignment Alignment was quantified using a coding scheme that compared the similarity between the sign a participant produced, and the sign their partner produced on the previous game when communicating the same concept. Ratings were made on a 7-point likert scale, where 0 indicates that the participant did not copy the sign previously used by their partner at all, and 6 represents a near identical copy of the partner's previous sign. A single alignment rating was made for each concept between games (i.e., between games 1-2, 2-3, 3-4, 4-5, 5-6).

Sign similarity was coded by one person (CJL). To establish reliability, signs produced by 12 participant pairs in each condition, across all games, were coded by a second coder who was naïve to the experimental hypotheses. This gave 2592 independent codings for sign motivation (~20% of the data). Intraclass correlations demonstrated high reliability between the coders for signs produced in the Gesture-only (96%) and Vocal-only (91%) conditions ($ps < .001$).

Hypothesis 3 was that alignment would be higher in the gesture-only condition than in the vocal-only condition. Participants' alignment scores were entered into a three-way, repeated measures ANOVA that treated Modality (Gestural, Vocal), Game (2-6) and Concept (Adjective, Noun, Verb) as within-participants factors. This returned a significant main effect of Condition, $F(1, 52) = 437.74, p < .001$, confirming that participants who gestured aligned more than those who vocalized; and a significant main effect of Game, $F(4, 208) = 256.49, p < .001$, reflecting increased alignment in both conditions across games. There was also a significant main effect of Concept, $F(2, 104) = 3.39, p = .04$, with pairwise comparisons showing significantly more alignment upon signs for nouns than for adjectives, $p < .01$. There was no difference in alignment between adjectives and verbs, or nouns and verbs, $ps > .05$.

Finally, there was a significant interaction between Game and Condition, $F(4, 208) = 4.12, p = .003$. To examine the nature of the interaction, difference scores were calculated for alignment at game 2 and at game 6. A paired samples t-test confirmed that difference scores were significantly higher at game 6 ($M = 2.84, SD = 1.09$) than at game 2 ($M = 2.51, SD = .84$), $t(52) = -2.52, p = .02, d = .70$. This indicates that the difference in alignment between the gesture and vocal modality increased across games.

Motivation, Communication Success and Alignment

Fay et al. (2014) speculated that greater sign motivation led to greater communication success. They also demonstrated that greater communication success led to increased alignment. We conducted bivariate correlations to explore the relationships between all three variables (collapsed across conditions). These revealed strong positive relationships between identification accuracy and alignment, $r(52) = .87, p < .001$ (see Figure 2), identification accuracy and sign motivation, $r(52) = .79, p < .001$ (see Figure 3), and sign motivation and alignment, $r(52) = .85, p < .001$. The strong relationships observed between sign motivation and identification accuracy, and identification accuracy and alignment, suggest that these processes are intimately linked, with increased motivation facilitating accurate

identification, and greater identification accuracy leading to increased alignment between interacting dyads.

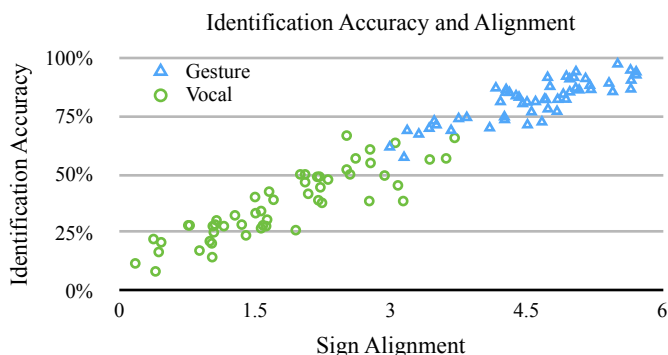


Figure 2: Relationship between identification accuracy and alignment in the Gesture and Vocal conditions.

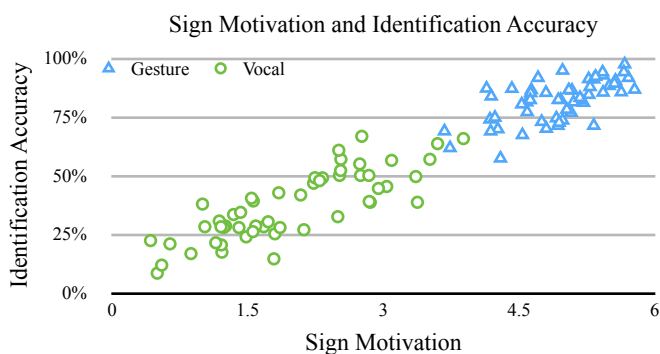


Figure 3: Relationship between sign motivation and identification accuracy in the Gesture and Vocal conditions.

Experiment 2

Experiment 2 addresses a potential limitation of Experiment 1. To prevent participants in the vocal-only condition conveying meanings to their partner through gesture, Experiment 1 participants sat back-to-back during the experiment. However, this may have disadvantaged participants in the vocal-only condition by preventing them from seeing their partner's facial expressions of confusion or comprehension. This type of concurrent feedback was possible in the gesture-only condition, but not in the vocal-only condition. Experiment 2 addresses this issue. The vocal-only and gesture-only conditions of Experiment 2 are non-interactive, thereby eliminating all concurrent feedback. In Experiment 2 participants try to communicate each concept alone, and the sign they produce (vocal or gestured) is recorded and played back to a partner who tries to identify the intended meaning, and then tries to communicate each of the concepts themselves (again recorded). Sign motivation, communication success and alignment are measured. We expect greater sign motivation, increased identification accuracy, and greater alignment in the gesture-only condition than in the vocal-only condition. We expect to find positive correlations between each of these measures, as in Experiment 1.

Method

All participants viewed an information sheet before giving written consent to take part in Experiment 2. Information sheets and consent forms were approved by the University of Western Australia Ethics Committee.

Participants Sixty undergraduate students (42 females) participated in exchange for partial course credit, and completed the testing session in ~30 minutes. All were free of auditory, visual, speech and motor impairments.

Materials The corpus of concepts used in Experiment 2 is the same as that used in Experiment 1. As fewer participants took part in Experiment 2, fewer concepts were sampled (540).

Task and Procedure As in Experiment 1, Experiment 2 participants produced gesture and vocal signs to communicate lists of concepts. However, participants in Experiment 2 took part individually, communicating signs to a video camera instead of a partner. Consequently, testing for Experiment 2 took place in two stages. At stage one, participants communicated their list of concepts to a camera (acting as Director). At stage two, their partner viewed these recordings, and tried to guess which concepts were being communicated (acting as Matcher). They were then presented with the same list of concepts they had viewed in the recording (in a different order), and asked to communicate these concepts to the camera.

Again Directors were presented with one concept at a time on an iPad. As opposed to waiting for a partner to make their guess (Experiment 1), Directors clicked a button to progress to the next concept. When Matching, participants were presented with all 18 target concepts, plus 6 distractor concepts, and made their guesses using the touch screen on an iPad. All participants took part in the Gesture-only and Vocal-only conditions. Only two games were played, as opposed to six games in Experiment 1.

Results and Discussion

Sign motivation, communication success and sign alignment were measured. To establish reliability, one coder rated all signs for motivation and alignment (CJL). A second coder rated the signs produced by 10 participant pairs in each condition, across all games (~33% of the data). Intraclass correlations demonstrated high inter-rater reliability for the motivation ratings in the Gestural (84%) and Vocal (85%) modalities, and for alignment ratings in the Gestural (92%) and Vocal (91%) modalities, ($ps < .001$).

Motivation A three-way, repeated measures ANOVA that treated Modality (Gestural, Vocal), Game (1-6) and Concept (Adjective, Noun, Verb) as within-participants factors, was run. There was a main effect of Condition, $F(1, 29) = 561.28, p < .001$, confirming that gestured signs were more motivated than vocal signs, and a main effect for Concept, $F(2, 58) = 3.95, p = .03$.

Paired samples t-tests showed no significant differences between the motivation of different concepts in the vocalization condition. However, in the gesture condition, verbs were communicated more successfully than adjectives and nouns $t_s(29) > -2.30, ps < .04, ds < .85$ (see Figure 4). There was no main effect for Game, and there were no interaction effects, [$F_s(1, 29) < .239, ps > .13$].

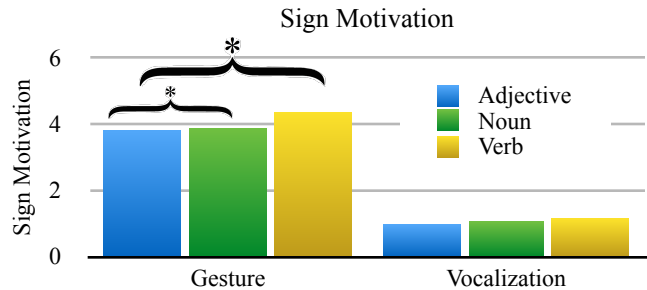


Figure 4: Motivation averaged across games 1 and 2.
Note: * $p < .05$

Communication Success A two-way, repeated measures ANOVA that treated Modality (Gestural, Vocal) and Concept (Adjective, Noun, Verb) as within-participants factors was run on participants' mean identification accuracy scores at game 1. There was a main effect of Condition, $F(1, 29) = 95.99, p < .001$, confirming that gestured signs were communicated more successfully than vocal signs. We found no effect of Concept on identification accuracy, and no interaction effects [$F_s(2, 58) < 2.82, ps > .07$].

Alignment A two-way repeated measures ANOVA that treated Modality (Gestural, Vocal) and Concept (Adjective, Noun, Verb) as within-participants factors was run on participants' mean alignment scores at game 2. There was a main effect of Condition, $F(1, 29) = 283.41, p < .001$, confirming that participants aligned more when gesturing than when vocalizing. There was no effect of Concept, and there were no interaction effects [$F_s(2, 58) < 2.20, ps > .12$].

Bivariate correlations were run on identification accuracy, alignment and sign motivation (motivation scores were averaged across game 1 and 2). In the Gesture condition, moderate positive relationships were found between identification accuracy and alignment, $r(28) = .53, p < .001$, identification accuracy and motivation, $r(28) = .64, p < .001$ and motivation and alignment, $r(28) = .61, p < .001$. In the Vocalization condition, a moderate correlation was found between identification accuracy and alignment, $r(28) = .59, p < .001$, and strong correlations were observed between identification accuracy and motivation, $r(28) = .75, p < .001$, and motivation and alignment, $r(28) = .71, p < .001$.

Experiment 2 replicated the pattern of results observed in Experiment 1. By removing participant interaction from both conditions, we eliminated any advantage participants may have had from being face-to-face when gesturing in Experiment 1. This indicates that the benefit of gesture over non-linguistic vocalization observed in Experiment 1 is due to the modality itself rather than concurrent feedback.

General Discussion

Experiments 1 and 2 replicate and extend the findings of similar experimental semiotic studies (e.g., Fay et al., 2014; Perlman et al., 2014). Increasing the set of concepts communicated eliminates the possibility that our results are a consequence of the specific experimental stimuli used. In line with Hypothesis 1, gestured signs were more strongly motivated than vocal signs. Identification accuracy was also higher in the Gesture-only condition, supporting Hypothesis 2. These results support the suggestion that participants who gesture outperform those who vocalize because gesture more naturally lends itself to the production of motivated signs (Fay et al., 2014)

Hypothesis 3, that alignment would be greater in the Gesture-only condition, was also supported. This finding confirms that of Fay et al. (2014), and further demonstrates the superiority of gesture over non-linguistic vocalization when bootstrapping a shared sign system. Furthermore, the strong correlation observed between sign motivation and identification accuracy in the current study suggests that motivated signs facilitate comprehension when interacting partners are unable to draw on their common language. The correlation between identification accuracy and alignment supports the observations of Fay et al. (2014), who suggested that these processes are mutually reinforcing (i.e., increased identification accuracy fosters greater alignment, and vice-versa). We argue that motivated signs foster mutual comprehension, and that comprehension promotes sign alignment, which reinforces comprehension (Figure 5).

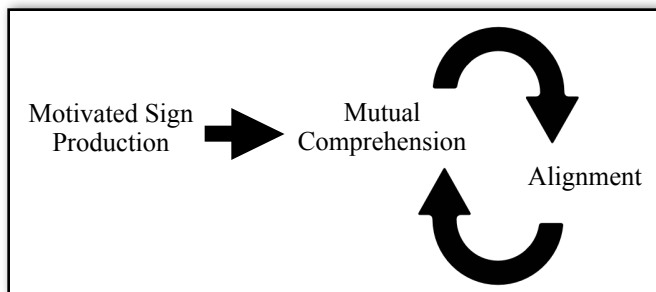


Figure 5: Proposed relationship between sign motivation, mutual comprehension, and alignment.

Because gesture more naturally lends itself to the production of motivated signs than non-linguistic vocalization, it follows that communication success and sign alignment will be higher in the gesture modality.

Experiment 2 returned the same pattern of results observed in Experiment 1, confirming the superiority of gesture over vocalization even when concurrent feedback between pairs of participants is eliminated. Interestingly, in the Gesture condition, motivation scores from Experiment 2 differed by Concept type; signs participants produced for Verbs were significantly more motivated than for Nouns or Adjectives. This was not observed in Experiment 1, perhaps because in Experiment 1 participants felt more pressured to convey each concept as thoroughly as possible (owing to the presence of a partner). Supporting this suggestion, participants in Experiment 2 made fewer communicative

attempts per concept than those in Experiment 1. Under less demanding circumstances, participants in Experiment 2 may have made less effort to communicate more challenging (i.e., less motivated) noun and adjective concepts. Thus, the gestures produced for nouns and adjectives were less motivated than for the comparatively easier verbs.

Returning to theories of language origin, our results support an account in which gesture played a pivotal role. In the absence of conventional language, it is likely that our ancestors would have relied heavily upon motivated signs, particularly gestured signs, to get their point across.

Acknowledgments

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