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People Are Less Susceptible to Illusion When They Use Their Hands to Communicate Rather Than Estimate

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Abstract

When we use our hands to estimate the length of a stick in the Müller-Lyer illusion, we are highly susceptible to the illusion. But when we prepare to act on sticks under the same conditions, we are significantly less susceptible. Here, we asked whether people are susceptible to illusion when they use their hands not to act on objects but to describe them in spontaneous co-speech gestures or conventional sign languages of the deaf. Thirty-two English speakers and 13 American Sign Language signers used their hands to act on, estimate the length of, and describe sticks eliciting the Müller-Lyer illusion. For both gesture and sign, the magnitude of illusion in the description task was smaller than the magnitude of illusion in the estimation task and not different from the magnitude of illusion in the action task. The mechanisms responsible for producing gesture in speech and sign thus appear to operate not on percepts involved in estimation but on percepts derived from the way we act on objects.

Keywords

deaf, gestures, language, sign language, visual illusion, open data, open materials

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When people describe their experiences with objects, they often gesture with their hands as they talk. These gestures are tightly integrated with the speech they accompany, and gesture and speech are the product of a single or highly interactive processing system (Kendon, 1980; Kita & Özyürek, 2003; McNeill, 1992). Indeed, the form of the gestures that speakers produce is shaped, in part, by the type of language they speak (Gullberg et al., 2008; Özçalışkan et al., 2016; Özyürek et al., 2008). Co-speech gesture thus works in concert with the spoken system to achieve a single multimodal utterance and is influenced by that system.

However, within this integrated system, speakers often produce gesture that conveys information not found in the speech it accompanies (Goldin-Meadow, 2003; Kita & Özyürek, 2003). For example, when asked to describe how they moved disks in a Tower of Hanoi puzzle, speakers never mention the weight of the disks in their speech. But they indicate weight in their co-speech gestures by moving either one hand (for a light disk) or two hands (for a heavy disk). Importantly, the number of hands they use in gesture predicts their subsequent performance on the puzzle, revealing gesture's relevance to cognition (Beilock & Goldin-Meadow, 2010; Goldin-Meadow & Beilock, 2010). Co-speech gesture is influenced by the action it reflects.

Thus, there is tension between theories of gesture production—how much is gesture influenced by the linguistic system with which it is integrated as opposed to the action system after which it is often modeled? We turn to a well-researched area in psychophysics to address this question.

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The Müller-Lyer illusion is one of the most robust tricks that our eyes play on us. We reliably overestimate the length of a stick when that stick is surrounded by open fins compared with closed fins (Fig. 1; Foster, 1923). Interestingly, our hands are not deceived—when asked to grasp the stick, we anticipate the length of the stick relatively accurately whether it is surrounded by open or closed fins. In other words, our hands are less susceptible to illusion than our eyes (Aglioti et al., 1995; Bruno & Franz, 2009).

Our first question is whether this phenomenon holds when we use our hands not to act on objects but to describe them in co-speech gesture. People are strongly influenced by the Müller-Lyer illusion when asked to make spoken judgments about stick length (van Doorn et al., 2007). We might therefore expect co-speech gesture to be highly susceptible to visual illusion because gesture forms an integrated system with speech. But we also know that co-speech gesture reflects kinematic features of the actions on the manipulable object the gesture represents (Cook & Tanenhaus, 2009; Pouw et al., 2020). Because co-speech gesture is thought to be grounded in manual action routines (Beilock, 2009; Chu & Kita, 2016; Hostetter & Alibali, 2008; Kita et al., 2017), it might be relatively immune to visual illusion. We might therefore expect co-speech gesture to be no more susceptible to visual illusion than a hand on its way to grasp an object.

The hand shapes that speakers produce when they gesture are created on the spot and thus not codified. Our second question is whether this lack of standardization impacts how susceptible the hand is to visual illusion. We addressed this question by turning to sign languages of the deaf—conventionalized linguistic systems performed by the hand and body. American Sign Language (ASL) has four linguistic categories expressed in specific hand shapes that signers can use to describe the four sticks in our task (Brentari, 1998; Eccarius, 2008; Fig. 2). Because they are linguistic categories, the four hand shapes might be resistant to the impact of visual illusion. If so, signers should not alter their hand shapes regardless of whether they are viewing a stick presented with fins or without fins. Their descriptions might then be less susceptible to visual illusion than speakers' descriptions.

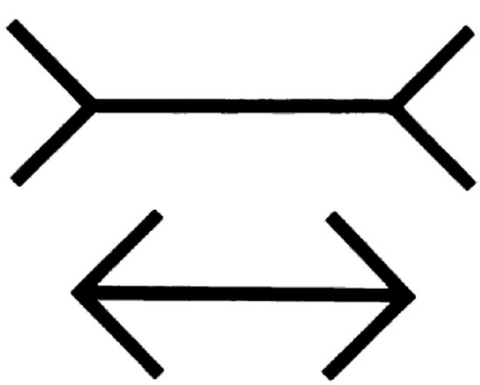

Fig. 1. The Müller-Lyer illusion. Both of the horizontal lines are the same length. However, the closed configuration (closed fins) makes the center line appear shorter than the open configuration (open fins).

Statement of Relevance

Sometimes our eyes deceive us. One famous visual illusion involves judging the length of sticks. In this illusion, when we use our hands to estimate the length of a stick, we are susceptible to the illusion––our eyes are misled. Interestingly, when we are not estimating the stick's length but are instead preparing to grasp it, we are much less susceptible to the illusion—our hands are not deceived. We asked whether this phenomenon holds when we use our hands to spontaneously describe the stick, either when gesturing while speaking English or signing American Sign Language. We found that gesturers and signers did not reveal any particular susceptibility to illusion when they used their hands to communicate about stick length. Their hands moved like hands preparing to act on an object in terms of illusion size, not like hands estimating the size of the object. Even though gesture and sign are tightly tied to language, their roots may lie in action.

But signers also gesture (Emmorey, 1999; Lu & Goldin-Meadow, 2018), although it can be difficult to isolate the categorical components of sign from its more gestural components (Goldin-Meadow & Brentari, 2017). Each of the four hand shapes in Figure 2 is a linguistic category, but within each category, signers can use a slightly wider or narrower grip aperture to capture stick size, thus adding a gestural component to their signs (Duncan, 2005; Emmorey & Herzig, 2003). As a result, signers have gestural means to capture the visual illusion in their descriptions of the sticks. The fact that gesture is an integral part of sign might then lead us to expect signers to display the same level of visual illusion in their manual descriptions as speakers do in their co-speech gestures.

We explored these possibilities by comparing hand shapes produced by ASL signers, who were asked to describe how they moved an object, with hand shapes produced in co-speech gesture by English speakers, who were asked to describe the same objects and movements. We first replicated the established phenomenon

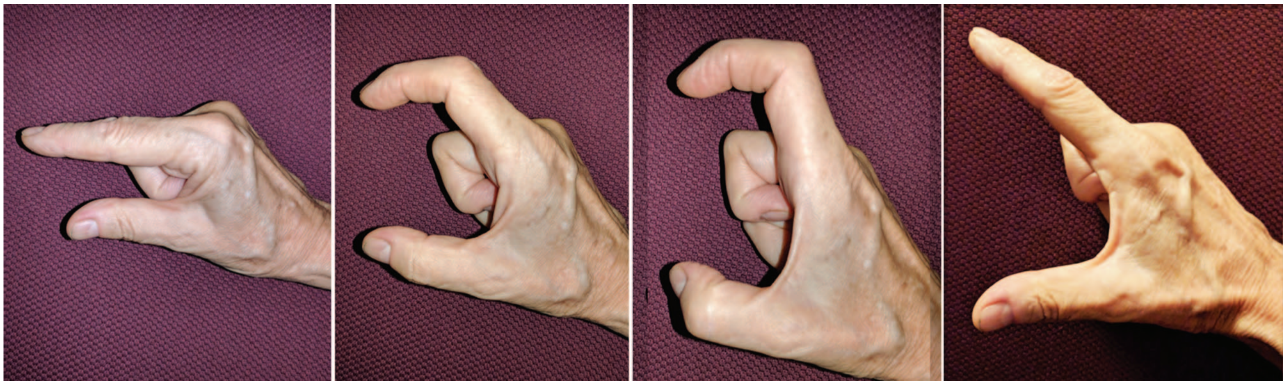

Fig. 2. The American Sign Language hand shapes that signers had available to represent the four sticks of increasing lengths (from left to right: 50 mm, 70 mm, 90 mm, 110 mm) used in our task.

that people are more susceptible to the Müller-Lyer illusion when they estimate the length of the stick with their hands than when they actually reach to grab the stick. We then situated how the hands are used to describe the stick, in sign or in co-speech gesture, between the two poles of estimation and action.

Method

Participants

Forty-five right-handed adults (ages 19–68 years, 23 female) participated: 32 adults whose primary language is English were recruited from the study pool at The University of Chicago, and 13 adults whose primary language is ASL were recruited at a local deaf event or through e-mail advertisements (all 13 were deaf and learned ASL before the age of 6 years). Sample size was determined, first, by effect and sample sizes from the literature and, second, by pilot data from English-speaking participants. The sample size was smaller for signers than for speakers because deaf participants who learned ASL early in life are difficult to locate. However, the sample size for the deaf participants was similar to sample sizes used in previous studies (n = 14) that showed that estimation is more susceptible than action to visual illusion in both the Ebbinghaus illusion (Aglioti et al., 1995) and the Müller-Lyer illusion (Meegan et al., 2004). We also took repeated measurements in each condition to increase the precision of our effect estimates. Participants self-reported normal or corrected-to-normal vision (wearing glasses or contacts) and completed the Edinburgh Handedness Inventory (Oldfield, 1971 to verify right-handedness. Left-handed participants were excluded.

Tasks and procedure

Using motion-capture technology, we recorded participants' manual movements as they performed tasks with four thin sticks of different lengths (50 mm, 70 mm, 90 mm, 110 mm). Each stick was placed on a background image that created the Müller-Lyer illusion, surrounding the stick with open fins or closed fins (Fig. 1; Goodale et al., 1994). Participants were also presented with a set of sticks with no background image (i.e., without fins). Thus, the procedure contained 12 displays, presented in pseudorandom order and repeated eight times in separate blocks for each task.

Participants were instructed to sit at a table and form their right hand into a fist with the thumb and forefinger extended and pressed together at the tips (see Fig. S1 in the Supplemental Material available online). They were then asked to place their fist on a mark on the table. During a training period for each task, video models demonstrated how to perform the task; participants were given feedback if they did not perform the task as demonstrated. For each trial, participants were asked to close their eyes while the experimenter placed one of the visual displays on the table in front of them. When instructed to do so by the experimenter, participants opened their eyes and performed one of three tasks. Each participant performed all three tasks (see Fig. 3). The order of the first task (action or estimation) was counterbalanced across trial days. The description task was always performed last on each day. Example videos from the tasks can be found on our OSF page (https://osf.io/3rb6u/).

Each participant completed the procedure twice over 2 days, resulting in 96 possible observations of descriptions, 168 observations of actions, and 72 observations of estimations per participant (the action of picking up the stick was repeated in the description task, increasing the amount of action data available for analysis).

We measured how wide the thumb and forefinger opened (maximum grip aperture) in each task. On the basis of previous work, we anticipated that grip apertures would differ in the action and estimation tasks (Bruno

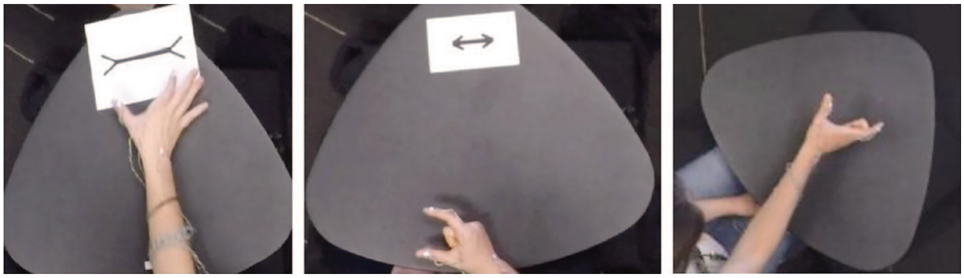

Fig. 3. Examples of a participant performing the action task (left), the estimation task (middle), and the description task (right). Example videos from the tasks can be found at https://osf.io/3rb6u/.

& Franz, 2009). However, it was unclear how speakers' and signers' grip apertures would vary in the description task.

Action task. Participants used their right hand to pick up the stick in the display, holding it at the two ends, and immediately set it down again on the table. They then returned their hand to the starting position.

Estimation task. Participants estimated the length of the stick in the display by holding the thumb and forefinger of their right hand the appropriate distance apart. During this task, they maintained the natural position of the wrist with hand on the table, perpendicular to the stimulus on the table. Previous studies have used both parallel and perpendicular presentations of stimuli and found similar effects (Bruno & Franz, 2009); we chose to maintain the natural position of the wrist during estimation to reduce awkwardness while holding the hand steady. Participants were instructed to say "ready" (speakers) or nod their head (signers) when they had settled on their estimate. To ensure that participants received haptic feedback from the stick, we asked them to pick up the stick after making their estimate and to set it down on the table again, returning their hand to the starting position.

Description task. Participants watched a video of a hand holding a 20-mm white disk tracing a unique path of motion over a neutral background (approximately 5 s). When the video ended, participants were instructed to close their eyes, and an experimenter placed the visual display on the table in front of the participant. Participants were told to open their eyes, pick up the stick in the display, and perform the movement they had seen in the video. When they completed the movement, they placed the stick on the table and returned their hand to the starting position. Participants were then asked to close their eyes again, and the experimenter removed the materials from the table. When prompted, participants opened their eyes and described the movements they had just performed with the stick. Participants were instructed to provide a description of the movement they had just performed in enough detail that someone who did not see the movement could perform it exactly as they had. Participants were told that they should move their hand from the starting mark while describing their actions and return their hand to the starting position when they finished describing their actions. An example of the movement performed in the description task can be found on our OSF page (https://osf.io/3rb6u/).

Data analysis

We performed hierarchical linear modeling with the *lme4* package (Bates et al., 2014) in the R programming environment (Version 3.6.3; R Core Team, 2020). We fitted a linear mixed-effects model with maximum grip aperture as the outcome variable and fixed effects of stick size, illusion display, task, and their three-way interaction: maximum grip ~ Stick × Fins × Task + (1 + Stick × Fins| subject). We fitted a maximal random-effects structure, which included random slopes for stick, fins, and their interaction by participant. We fitted separate models with the same fixed-effects and random-effects structure for ASL and co-speech gesture as outcome variables.

Results

To compare the results of our tasks, we examined two measures. The *grip scaling slope* is the relation between the maximum grip aperture and the size of its target object for the four stick lengths. This measure indicates how accurately participants captured the increases in stick sizes—positive slopes indicate that the hand shape increased as the lengths of the sticks increases. The *illusion effect* is the difference between grip apertures in the closed-fins condition and the open-fins condition.

This measure indicates how influenced participants were by the illusion—a large difference indicates that the participants were strongly influenced. Figure 4 presents the predictions of the linear mixed-effects model for the effects on maximum grip apertures of stick size (grip scaling slope) and illusion background (illusion effect) for signers and speakers in each of the three tasks.

Action versus estimation tasks

Not surprisingly, when grasping the objects in the action task, signers and speakers increased grip apertures as the sticks increased in length, resulting in a positive grip scaling slope (signers: slope b = 6.96-mm increase per 10-mm increase in stick size, 95% confidence interval [CI] = [6.27, 7.64]; speakers: slope b = 7.10-mm increase per 10-mm increase in stick size, 95% CI = [6.79, 7.40]; Fig. 4). Similarly, when estimating the size of the stick, signers and speakers also increased grip apertures as the sticks increased in length (signers: slope b = 8.93-mm increase per 10-mm increase in stick size, 95% CI = [8.20, 9.66]; speakers: slope b = 8.35-mm increase per 10-mm increase in stick size, 95% CI = [7.99, 8.70]; Fig. 4). Both groups thus captured the increasing lengths of the objects in their grip apertures, as expected. CIs for signers' and speakers' grip scaling slopes overlap for action and for estimation. This finding supports the conclusion that the grip scaling slopes (or rate of increase in grip apertures as objects get bigger) for action and estimation are not statistically different between signers and speakers.

For the illusion effect, signers and speakers used wider grip apertures for sticks presented between open fins than for sticks presented between closed fins when grasping the sticks in the action task (open – closed), signers: b = 2.31 mm, 95% CI = [0.74, 3.88], p = .005, d = 0.17; speakers: b = 1.14 mm, 95% CI = [0.24, 2.04], p = .013, d = 0.09, and when estimating stick length, signers: b = 10.22 mm, 95% CI = [8.22, 12.22], p < .0001, d = 0.77; speakers: b = 7.54 mm, 95% CI = [6.37, 8.71], p < .0001, d = 0.58. In addition, as in previous studies (Bruno & Franz, 2009), post hoc t tests (Tukey corrected) confirmed that the size of the illusion effect (i.e., the difference between grip apertures for open vs. closed fins) was significantly greater in the estimation task than in the action task for both signers and speakers (estimation – action), signers: b = 7.91 mm, SE = 1.23, p < .0001, d = 0.15; speakers: b = 6.40 mm, SE = 0.72, p < .0001, d = 0.13. In other words, the effect of the illusion on grip apertures was stronger when participants estimated the size of the stick with their hands than when they reached to grasp the stick, for both signers and speakers.

Description task

Signers: ASL. When describing how they moved the stick, signers used an increasingly large grip aperture as the sticks increased in length, resulting in a positive grip scaling slope (b = 4.79-mm increase per 10-mm increase in stick length, 95% CI = [4.03, 5.55]; Fig. 4 and Table 1). However, post hoc t tests revealed that the grip scaling slope was significantly smaller in the description task than in both the estimation task (estimation – description), b = 4.14, SE = 0.327, t(1878) = 12.66, p < .0001, d = 0.31, and the action task (action – description), b = 2.17 mm, SE = 0.29, t(1880) = 7.52, p < .0001, d = 0.16. In other words, signers did not increase their grip apertures for larger sticks in the description task as much as they did in the action and estimation tasks, perhaps because their hand shapes in the description task were drawn from the linguistic categories that ASL signers can use to describe the four sticks in our task (Brentari, 1998; Eccarius, 2008; Fig. 2). The positive grip scaling slope indicates that their hand shapes did capture the increasing stick lengths.

With respect to the illusion effect (Table 1), signers used wider grip apertures for sticks between open fins than for sticks between closed fins when describing what they did with the stick (open – closed), b = 2.85 mm, SE = 1.12, t(114) = 2.55, p = .01, d = 0.21. However, post hoc tests revealed that the effect of the illusion on descriptions was significantly different from, and smaller than, the effect of the illusion on estimations (estimation – description), b = 7.37, SE = 1.47, t(1811) = 5.03, p < .001, d = 0.12, and not significantly different from the effect of the illusion on actions (action – description), b = −0.54, SE = 1.31, t(1843) = −0.41, p = .68, d = −0.01.

Speakers: co-speech gesture. When describing how they moved the stick, speakers also used an increasingly large grip aperture in their co-speech gestures as the sticks increased in length, resulting in a positive grip scaling slope (b = 1.92-mm increase per 10-mm increase in stick length, 95% CI = [1.55, 2.3]; Fig. 4 and Table 1). The grip scaling slope for speakers was significantly smaller in the description task than in the action task (action – description), b = 5.17, SE = 0.17, z = 29.88, p < .0001, d = 0.17, and estimation task (estimation – description), b = 6.42, SE = 0.19, z = 33.10, p < .0001, d = 0.32.

With respect to the illusion effect (Table 1), speakers used slightly wider grip apertures for sticks between open fins than for sticks between closed fins when describing what they did with the stick (open – closed), b = 0.72, SE = 0.66, z = 1.09, p = .28, d = 0.06; this difference was not statistically significant. As in signers' descriptions, post hoc t tests confirmed that the effect of the illusion on descriptions was significantly different from, and smaller than, the effect of the illusion on estimations

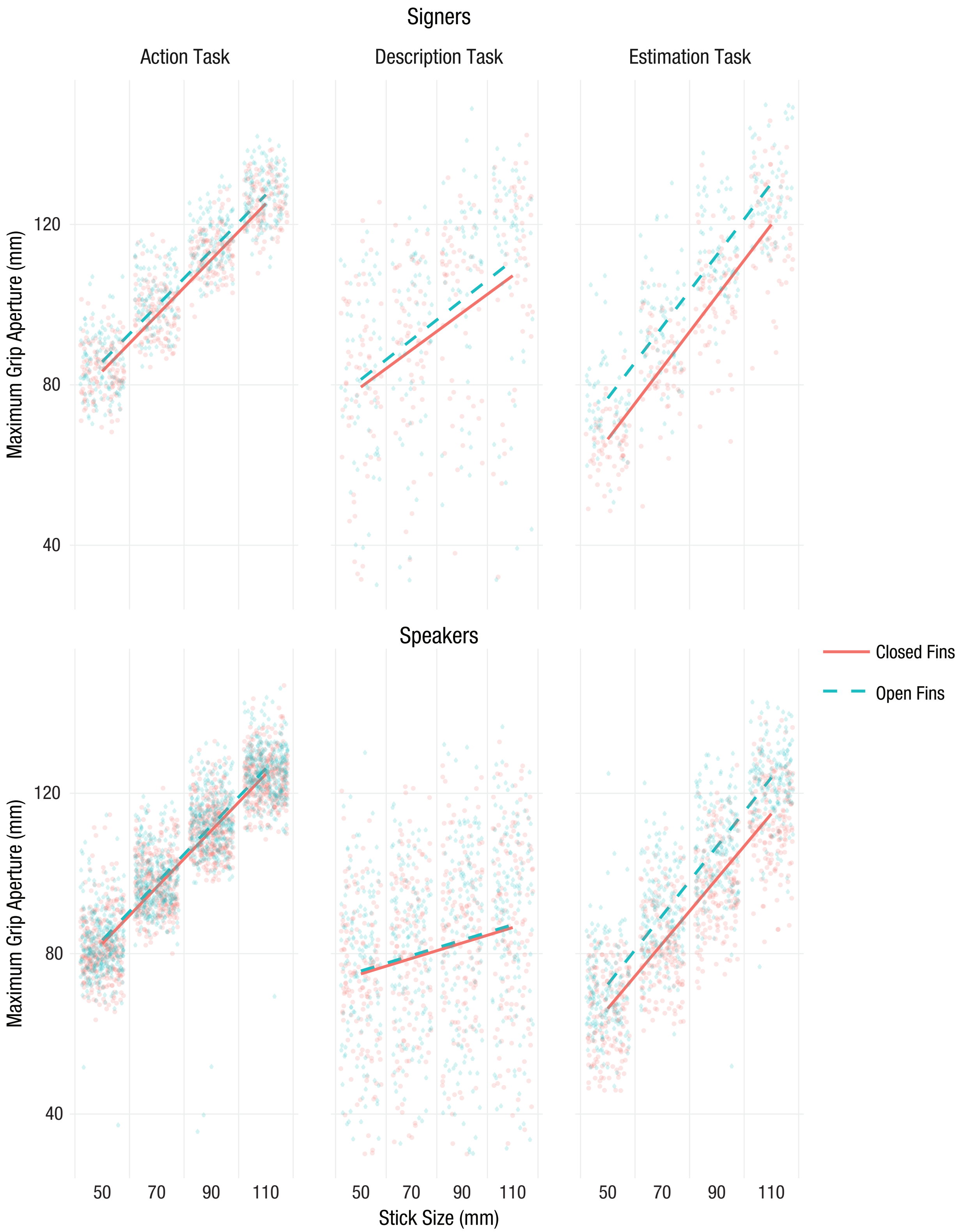

Fig. 4. Predictions of the linear mixed-effects model for the effects of stick size (50 mm, 70 mm, 90 mm, 110 mm) and illusion background (closed fins, open fins) on maximum grip apertures for the three tasks (action, description, estimation). Results are shown separately for the 13 signers (top row) and 32 speakers (bottom row). Intercept, grip scaling slope, and illusion effect were allowed to vary randomly by subject. Grip scaling slope is the average increase in grip aperture per 10-mm increase in stick length. Illusion effect is the average difference in grip apertures for sticks placed between illusion displays with open fins and closed fins. Dots show individual participants' data, and solid and dashed lines show best-fitting regressions.

Table 1. Mean Grip Scaling Slope and Illusion Effect for Signers and Speakers in the Three Tasks

	Grip scaling slope			Illusion effect		
Group	Action task	Description task	Estimation task	Action task	Description task	Estimation task
Signers	6.96*** [6.27, 7.64]	4.79*** [4.03, 5.55]	8.93*** [8.20, 9.66]	2.31** [0.74, 3.88]	2.85* [0.64, 5.06]	10.22*** [8.22, 12.22]
Speakers	7.10*** [6.79, 7.4]	1.92*** [1.55, 2.3]	8.35*** [7.99, 8.7]	1.14* [0.24, 2.04]	0.72 [−0.57, 2.02]	7.54*** [6.37, 8.71]

Note: Values in brackets are 95% confidence intervals; p values were adjusted using the Tukey method for comparing a family of three estimates. *$p < .05$. **$p < .01$. ***$p < .001$.

(estimation − description), $b = 6.82$, $SE = 0.86$, $z = 7.93$, $p < .001$, $d = 0.11$, and not significantly different from the effect of the illusion on actions (action − description), $b = 0.42$, $SE = 0.77$, $z = 0.54$, $p = .59$, $d = 0.01$.

Illusion effects as a function of grip scaling slope. We compared speakers and signers directly on the description task alone, examining the fixed effects of language on grip scaling slopes: maximum grip ~ Stick × Fins × Language + (1 + Stick × Fins | subject). Regression analyses confirmed that the grip scaling slope for description was significantly steeper for signers than for speakers (signers − speakers), $b = 3.14$, $SE = 0.63$, $t(35) = 4.97$, $p < .0001$, $d = 0.24$, indicating that speakers were not as good as the signers at capturing the actual size of the largest sticks in their manual descriptions, perhaps because the signers were drawing on established linguistic categories. However, on average, both groups reliably captured the relative sizes of the sticks.

It may be difficult to detect an illusion effect if descriptions did not capture the increasing lengths of the sticks. To explore this possibility, we assessed the illusion effect for each participant as a function of the grip scaling slope that the participant produced when there was no illusion display (i.e., when the sticks were presented without any fins). Figure 5 presents each participant's sensitivity to stick length, measured by grip scaling slope in a neutral context (sticks presented without fins; x-axis) in relation to that participant's sensitivity to illusory size cues, measured by the illusion effect (difference in grip apertures for the closed and open illusion displays; y-axis) for signers and speakers. For details on grip scaling slopes in neutral compared with nonneutral contexts for each of the three tasks, see Table S1 in the Supplemental Material.

Note that signers' grip scaling slopes in a neutral context are larger than those of speakers; indeed, there is no overlap between the groups. Moreover, signers displayed the same illusion effect no matter how steep their grip scaling slope—grip scaling slopes and illusion effects for signers are not significantly correlated, Pearson's $r(8) = .25$, $p = .48$, suggesting that the two are independent in signers. This independence is not surprising if grip scaling slope reflects signers' use of the four linguistic categories (Fig. 2) to capture increasing stick length in a neutral context, but the illusion effect reflects gestural variation within each category to capture length differences due to open versus closed fins. In contrast, we found a positive relation between participant grip scaling slope in a neutral context and the size of the illusion effect in speakers' co-speech gestures—the steeper the slope, the bigger the illusion effect, Pearson's $r(30) = .43$, $p = .015$. Unlike signers, speakers did not have linguistic categories to draw from—they used the same gestural system to represent the increasing lengths of the four sticks and to capture variation in length due to the open versus closed fins. Given this reasoning, the patterns in Figure 5 allow us to separate signers' linguistic use of hand shapes (which capture increasing stick lengths) from their gestural use of hand shapes (which capture differences between sticks with open and closed fins).

Summary

In summary, our goal was to determine how spontaneous descriptions that signers and speakers produce with their hands compare with the actions and estimations they produce with their hands in the same context, focusing on two features: (a) how well the hand reflects properties of the object—in this case, increasing stick length, or grip scaling slope—and (b) how susceptible the hand is to perceptual illusion—in this case, the Müller-Lyer illusion, or the illusion effect. With respect to grip scaling slope, we found that both signers and speakers captured increasing stick length in their hands better in the action and estimation tasks than in the description task. Signers were better than speakers at capturing stick length in the description task, presumably because they drew on an established set of linguistic categories; speakers relied on spontaneous gesture. But both groups captured relative stick length to some degree in their descriptions. With respect to the illusion effect, we first replicated previous work in speakers

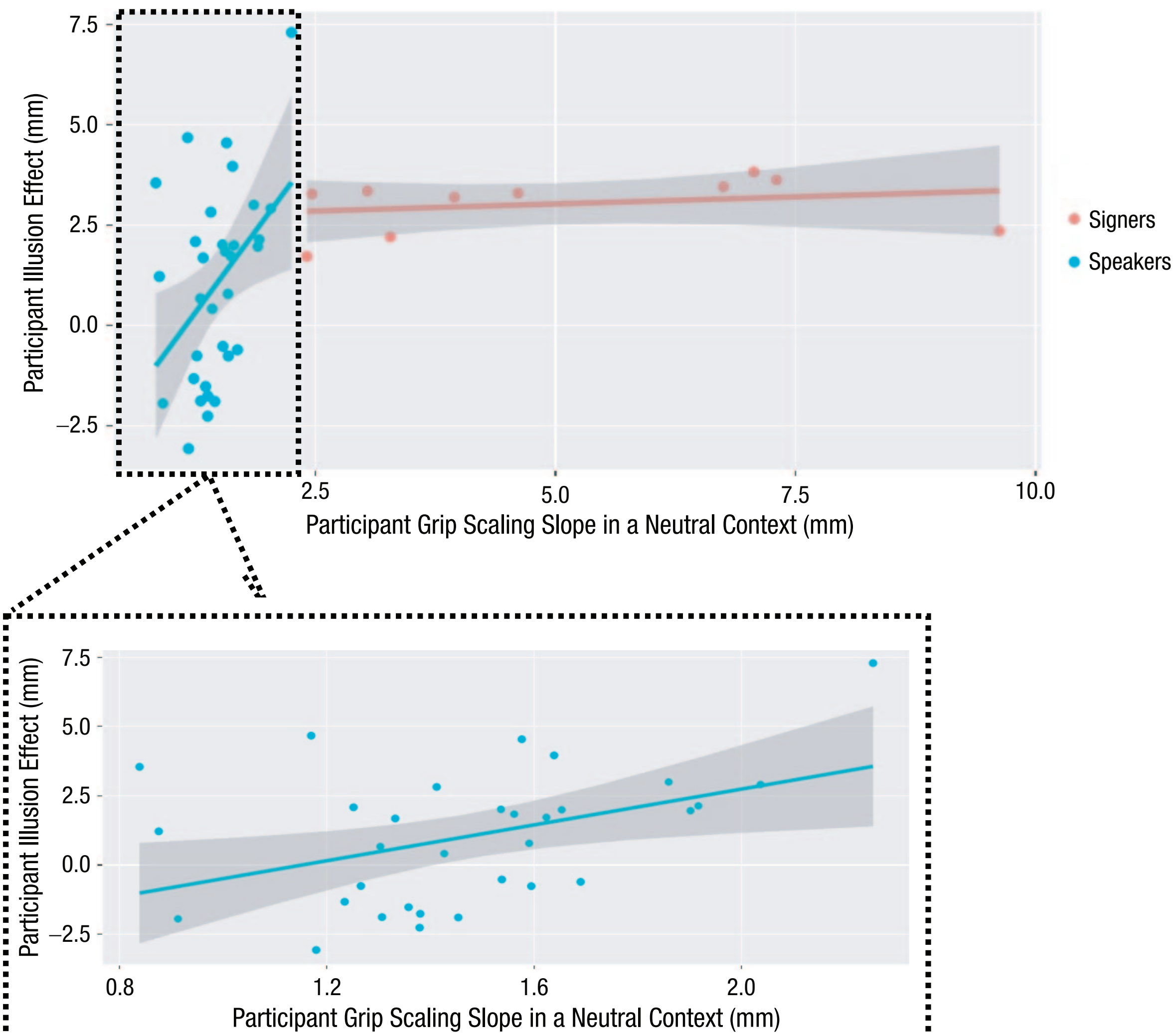

Fig. 5. Illusion effect as a function of grip scaling slope in the description task. The top graph shows results for both speakers and signers, and the inset graph enlarges the data for speakers, which do not overlap with the data for the signers. Grip scaling slope in a neutral context is the average increase in grip aperture per 10-mm increase in stick length when the sticks were presented without fins. Illusion effect is the average difference in grip apertures for sticks placed between illusion displays with open fins and closed fins. Dots represent individual data, and lines represent best-fitting regressions (error bands represent 95% confidence intervals).

showing that the hands are more susceptible to the Müller-Lyer illusion when they estimate stick length than when they reach to act on the same sticks, and we extended this effect to signers. Moreover, we found that the magnitude of the illusion effect in descriptions was significantly different from the magnitude of the illusion effect in estimations and not significantly different from the magnitude of the illusion effect in actions. Both signers and speakers showed this pattern.

Discussion

We found that descriptions produced by the hand were significantly less susceptible to perceptual illusions than estimations produced by the hand and not significantly different from actions produced by the hand. This finding is surprising on certain grounds—co-speech gesture forms an integrated system with speech and, thus, might be expected to be as susceptible to illusion as judgments made in speech (van Doorn et al., 2007). But it is not surprising on other grounds—co-speech gesture captures the kinematic aspects of the movements it represents (Cook & Tanenhaus, 2009; Pouw et al., 2020) and thus might be expected to be as protected from illusion as anticipatory action. The gestures in this study referred to absent objects and were scaled to visual illusory properties of these previously seen objects in a way that was comparable with actions performed directly on the objects. Our findings thus provide evidence that the mechanisms responsible for the production of co-speech gestures are based in action (see Chu & Kita, 2008, 2016; Hostetter & Alibali, 2008) and operate not on percepts involved in estimation but on percepts derived from action. One caveat, however, is that other types of gestures (e.g., gestures that are more abstract representations) might be less based in action than the gestures reflecting manual actions investigated here.

Not surprisingly, signers and speakers displayed the same patterns with respect to actions and estimations. The interesting question is how they perform with respect to descriptions. Sign languages are codified systems, which means that the hand shapes produced in sign are constrained in a way that the hand shapes produced in co-speech gestures are not. Signers used the hand shapes displayed in Figure 2 to describe moving the four sticks and, as a result, captured increasing stick length more accurately than speakers. Nevertheless, signers and gesturers displayed the same level of illusion effect in their manual descriptions—both displayed a significantly smaller illusion effect in descriptions than in estimations and no significant difference in illusion effect in descriptions and actions. Gesture may thus play the same role in sign and speech.

One potential problem with the design of our study is that the objects were taken away in the description task but were present in the estimation and action tasks. Note, however, that restricting vision so that action must be performed from memory makes even object-directed action susceptible to visual illusion (Westwood et al., 2001; Rinsma et al., 2017). More generally, when people's direct contact with the environment (either visual or haptic) is removed, visual illusions strengthen—when judging rather than acting (Aglioti et al., 1995), when seeing rather than also touching (Mancini et al., 2010), and when mimicking a grasp rather than actually grasping (Westwood et al., 2000). If removing the object in the description task did have an effect on our results, it is likely to have increased, rather than decreased, participants' susceptibility to illusion. The fact that we did not find a strong illusion effect in the description task is therefore not likely attributable to the absence of objects in the task.

Another possible explanation for our results is that participants did not display an illusion effect in their descriptions because the communicative situation did not require them to talk about stick length, and co-speech gesture often conveys information that is important in communication (Hoetjes et al., 2015; McNeill, 1992). Participants were asked to give a detailed-enough description of the movement they had just performed so that someone who did not see the event could perform it exactly as they had; the instructions thus did not require participants to focus on the length of the stick. There are two relevant questions here.

First, did participants encode stick length in their manual descriptions despite the fact that the instructions did not require it? Although participants were less accurate in their depictions of stick length in descriptions than in estimations and actions, they did capture increasing stick length in both their sign and co-speech gesture descriptions. The positive slopes in Figure 4 suggest that, even though stick length was not the point of the description, participants did encode it.

Second, what is the relation between stick length and the illusion effect? Participants captured stick length relatively accurately in both their estimations and actions. But the illusion effect was stronger in estimations than in actions (Fig. 4), suggesting that capturing stick length in hand shape does not guarantee that the hand will display the illusion effect. Moreover, signers displayed the same level of illusion effect no matter how accurately they captured the increasing lengths of the sticks (Fig. 5), suggesting that capturing stick length and displaying an illusion effect are relatively independent, at least in signers. However, we did find that the illusion effect got stronger in co-speech gesturers the more positive the slope of their grip accuracy, suggesting that the ability to capture stick length moderates the illusion effect in co-speech gesture.

One explanation for this relation might be that detecting an illusion effect is possible only when the participant displays a minimum level of grip accuracy (although some gesturers who produced grip scaling slopes as low as 0.8 mm did display an illusion effect of 3.1 mm, above the average effect for signers; Fig. 5). It is therefore possible that the illusion effect would increase for gesturers if their grip accuracy were to increase. Researchers can explore this possibility in future work by telling speakers to focus not only on the movements they performed but also on the length of the stick they moved. These instructions should make it more likely that speakers will capture increasing stick length in their gestures. The question is whether an increase in grip accuracy in co-speech gesture will bring with it an increase in illusion effect.

In this regard, we look to the literature on pantomimes, which have been extensively studied in psychophysical experiments of visual illusion (Cavina-Pratesi et al., 2011; Rinsma et al., 2017; Westwood et al., 2000; Whitwell et al., 2015). A pantomime is a deliberate repetition of an action, typically performed without speech, and thus differs from co-speech gestures, which are not deliberate (McNeill, 1992). Participants in psychophysical studies are often explicitly instructed to consider object size while performing a pantomime

(Rinsma et al., 2017; Whitwell et al., 2015), and they display a strong illusion effect (Westwood et al., 2000). If participants display a stronger illusion effect in their co-speech gestures when told to explicitly describe stick length (compared with when given no instructions about stick length), we would have evidence that focus on the relevant dimension in speech influences the hand's susceptibility to visual illusion (although it is worth noting that telling participants about the impact of open vs. closed fins on stick length does not typically diminish the illusion in speech).

In sum, because signers drew their hand shapes from an established set of linguistic categories, they were likely better poised than speakers to capture the increasing lengths of the four sticks in their manual descriptions. Nevertheless, the descriptions of signers and speakers displayed a comparable decrease in the illusion effect (relative to their estimations), suggesting that the gesture used in these descriptions may be comparable in sign and speech—both signers and speakers are more susceptible to the illusion effect in their estimations than in their descriptions or actions. The mechanisms responsible for the production of this type of gesture, in both sign and speech, thus appear to operate not on percepts involved in estimation but on percepts derived from action.

Transparency

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Author Contributions
S. Goldin-Meadow, A. R. Brown, and D. Brentari conceived of and designed the study. A. R. Brown collected the data and conducted the analyses in conjunction with W. Pouw. All the authors contributed to writing the manuscript and approved the final manuscript for submission.
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The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.
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Open Practices
Anonymized data, analysis scripts, and example videos from the tasks have been made publicly available via OSF and can be accessed at https://osf.io/3rb6u. The design and analysis plans for the study were not preregistered. This article has received the badge for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797621991552

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