Disturbed visual exploration of communicative gestures in aphasic patients: Evidence from eye movement analysis

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Abstract

Gestures are a crucial component of human non-verbal communication (Birdwhistell, 1970). Aphasic patients may display deficits in recognizing and producing gestures, preventing them from a successful use in communication (Hogrefe et al., 2012). The present study aimed to examine the perception of communicative and meaningless gestures in aphasic patients by means of eye movement analysis. Eighteen patients with aphasia and twenty healthy control participants took part in the study. Their visual exploration behavior was measured during the presentation of forty gestures (20 meaningless and 20 communicative gestures) by means of an infrared eye-tracking system. Mean and cumulative fixation duration were measured in different regions of interest (ROIs), such as the face, the gesturing hand, the body, and the surrounding environment. Significantly different patterns of visual exploration of communicative gestures were found in aphasic patients compared to healthy subjects. Aphasic patients fixated less the ROIs comprising the face or the gesturing hand during the exploration of communicative gestures. In contrast, aphasic patients explored more the environment. Patients and healthy participants did not differ in the visual exploration of meaningless gestures. Visual exploration of communicative gestures, but not of meaningless gestures, is disturbed in aphasic patients.

Keywords: Gesture perception; Aphasia; Eye movement analysis

Introduction

When people interact with each other, 65% of the communication takes place through non-verbal information such as speech pace, and gesturing (Birdwhistell, 1970). Gestures are defined as body movements that accompany or replace speech and that can convey a message (Kendon, 2004). However, gestures may also be movements that do not present a discernible meaning. The ability to correctly perceive and produce gestures seems important for human interaction. When verbal communication is impaired, such as in stroke patients with aphasia, the reliance on the use of gestures may increase to compensate for the speech deficit. Some patients make broad use of compensatory gestural strategies despite having severe aphasic deficits (Behrmann and Penn, 1984). However, other patients do not (Cicone et al. 1979). Eye movement recording is a reliable and valid technique to study visual exploration, which is fundamentally involved in perception (Henderson and Hollingworth, 1999). Only few studies examined eye movements during the visual exploration of gestures in healthy subjects (Beattie et al. 2010; Gullberg and Kita, 2009). The main finding of these studies was that the speaker's face is fixated as much as 90-95% of the total viewing time and gestures as less as 2-7%. However, it is not known how aphasic patients visually explore gestures and to what extent they fixate different regions of interest (ROIs), such as the face or the gesturing hand. The present study aimed to investigate the visual exploration of communicative and meaningless gestures in aphasic patients and in healthy subjects by means of eye movement analysis.

Subjects and methods

Subjects

Eighteen patients with aphasia after a first left hemispheric stroke (aged between 18-75 years, mean = 47.2, Standard deviation (SD) = 15.28, 6 women) and twenty healthy subjects (aged between 22- 85 years, mean = 42.6, SD = 18.59, 13 women) participated in this study. Aphasia classification and diagnosis was based on neurological examination and standardized diagnostic procedures conducted by professional language therapists (Delavier and Graham, 1981; Huber et al. 1983). All participants had normal or corrected-to-normal vision and hearing. Patients with hemianopia or right-sided visual neglect as assessed by standardized neuropsychological tests (Gauthier et al., 1989; Schenkenberg et al. 1980) were not included in the study.

Eye-tracking device

Forty stimuli were presented on the 22´´ screen of a RED eye-tracking system (SensoMotoric Instruments GmbH, Teltow, Germany). This infrared, video-based eye-tracking system is developed for contact-free measurement of eye movements, with an automatic head-movement compensation mechanism. Binocular images are analyzed in real-time by detecting the pupil and calculating its centre, and eliminating artifacts such as small head movements by tracking the corneal reflex. The BeGazeTM analysis software (SensoMotoric Instruments GmbH, Teltow, Germany) was used to visualize gaze patterns and to determine dynamic ROIs, such as the face and the gesturing hand. Dynamic ROIs allow a reliable detection of fixations in both the hold (i.e., the sudden cessation of a movement) and the stroke (i.e., the dynamic phase of an ongoing gesture). The size of the 2 ROIs (face and gesturing hand) was adjusted to be equal for all 40 stimuli. In addition, two other ROIs were defined, i.e., the upper body and the environment. These two additional ROIs were static in nature.

Procedure

Participants were seated in a comfortable position in front of an eye-tracking device at a distance between 60 and 80 cm. They were instructed to explore forty videos sequences, each sequence being five seconds containing one gesture not accompanied by any speech. Consequently forty gestures were performed by a human character and presented on the screen. The stimuli were assigned to two blocks consisting of twenty video sequences each, one block containing meaningless, 'abstract', finger and hand gestures, the other block containing emblematic, (e.g. waving goodbye) and tool-related, (e.g. demonstration of hammer use) gestures. Each block started with a 5-point calibration of the eye tracking system and a validation procedure. During both procedures, participants were instructed to fixate the calibration targets, which were shortly presented at defined locations on the monitor. Prior to each stimulus, a central fixation point was presented during 3 seconds, ensuring a common starting point of the exploration for all subjects.

Data analysis

Subjects' visual exploration behavior was evaluated by means of fixation durations within the four different ROIs (face, gesturing hand, body, and environment). Fixations shorter than 100 ms were excluded from further analysis. Fixation duration over the four different ROIs was computed for each gesture and then averaged (mean fixation duration) or summed (cumulative fixation duration) over all videos for each subject. The cumulative fixation duration represents the total time spent looking at a specific ROI. Subsequently, separate repeated measures ANOVAs were performed for each parameter (mean fixation duration and cumulative fixation duration), with the between-subjects factor 'group' (aphasic and healthy control subjects) and the within-subjects factors 'gesture type' (emblematic, tool-related, finger and hand gestures) and 'ROI' (face, gesturing hand, body, and environment). Sphericity was assessed by Mauchly's test. If the sphericity assumption was violated, the degrees of freedom were adjusted according to the Greenhouse-Geisser method. For post-hoc comparisons, t-tests were used to assess the differences between and within the two groups for each single fixation duration parameter. Post-hoc tests were Bonferroni-corrected for multiple comparisons. Pearson's correlation coefficients were calculated between Token test scores and fixation durations. The level of significance was set at $p < 0.05$ (two-tailed). All values are expressed as mean ± standard error of the mean (SEM).

Results

The repeated-measures ANOVA on the cumulative fixation duration yielded significant differences for the factors 'gesture type' ($F_{[3,108]} = 3.19$, $p < 0.05$, $\eta^2 = 0.08$) and 'ROI' ($F_{[3,108]} = 92.80$, $p < 0.0001$, $\eta^2 = 0.72$). Moreover, a significant three-way interaction was found between the factors 'gesture type x ROI x group' ($F_{[9,324]} = 2.36$, $p = 0.01$, $\eta^2 = 0.06$). Post-hoc analyses revealed significantly different cumulative fixation durations in aphasic patients compared to healthy subjects when exploring communicative emblematic and tool-related gestures. In contrast, no differences between the two groups were found for the meaningless gesture types (finger and hand postures). Aphasic patients fixated for a significantly shorter time the ROIs 'face' and 'gesturing hand' (both $p = 0.002$) when they visually explored emblematic gestures. In contrast, aphasic patients explored the ROI 'environment' for a significantly longer time ($p = 0.002$) (results are depicted in Figure 1). For tool-related gestures, significant differences ($p = 0.02$) were also found for the ROI 'face' and the ROI 'environment' (see Figure 2). No significant differences between the two groups were found for the ROI 'body'.

Figure 1:

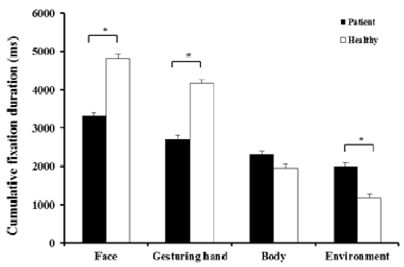
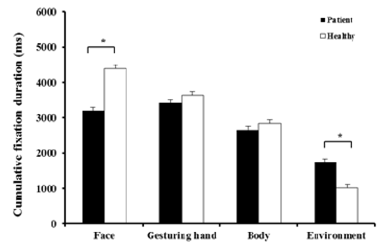


Figure 2:



Correlation analyses revealed no significant relationship between Token test scores and fixation duration parameters (r-values between 0.1 and 0.4, all p-values > 0.05).

Discussion

In the present study we found a disturbed visual exploration of communicative gestures, but not of meaningless gestures, in aphasic patients. When videos of communicative gestures were visually explored, aphasic patients fixated the face and the gesturing hand less than healthy subjects. In contrast, aphasic patients explored more the surrounding environment. The severity of aphasia did not seem to influence visual exploration behavior, and this was noted for all gesture types. Two main reasons why aphasic patients showed a different visual exploration behavior are conceivable. One possibility could be an underlying non-verbal semantic processing deficit. It is known that the presence of such a deficit may hinder aphasic patients in the recognition of symbolic gestures (Gainotti & Lemmo, 1976). Since eye movements in visual exploration are primarily driven by stored semantic knowledge (Hwang et al. 2011), a non-verbal semantic deficit in aphasic patients may explain why, in communicative gestures, gesture-relevant ROIs were less explored. Instead, aphasic patients explored more the environment than healthy controls, which contained no specific semantic information. This different exploration behavior was also independent of the severity of aphasic deficits, further supporting the possible involvement of such a non-verbal semantic deficit. Another possibility could be a gestural perceptual deficit in aphasic patients, explained within a cognitive model of gestural processing (Rothi, 1997). This model postulates that damage to the action semantic system or disturbed access to an input action lexicon leads to disturbed gesture recognition. The input action lexicon contains information relative to a code of the physical attributes of perceived actions (Rothi, 1997). It receives the "to-be perceived" information arising from a visual gestural analysis. This information is subsequently sent to the action semantic system, in which the conceptual features associated to the physical attributes of a gesture are recollected. Based on our results, we can also assume that aphasic patients perceived less semantic information, leading to a reduced supply of the action semantic system, and thus possibly explaining some of the deficits of these patients in meaningful gesture recognition (Gainotti & Lemmo, 1976). No differences in visual exploration were found between the ROIs face and the gesturing hand, for communicative gestures, in both aphasic patients and healthy participants. Our findings indicate that the face and the gesturing hand play an equally important role, when gestures are visually explored. The much higher amount of fixations to gestures seems not to be in line with the results of previous studies (Beattie et al. 2010; Gullberg and Kita, 2009), which found a clear dominance of visual exploration towards the face. However, this difference may be due to two main factors. First, we investigated 'pure' gestural perception, i.e. gestures, that were not accompanied by any speech or any mouth movement. Thus, the face and mouth was less salient. Second, in contrast to the previous studies, the analysis of dynamic ROIs allowed to reliably detect fixations during both holds and strokes of an on-going gesture. Therefore, the detection of fixations in dynamic ROIs was more accurate. In conclusion, our study demonstrated that visual exploration of communicative gestures is disturbed in aphasic patients. The different visual exploration behavior towards these gestures types could explain some gestural action deficits in aphasic patients. However, the exact relationship between gestural action and perception will have to be explored more profoundly. Furthermore, the different aspects of speech comprehension and production in relationship with exploration behavior will have to be investigated, since the gesture videos we used were without speech. Some preliminary findings, regarding before mentioned aspects, will be presented at the TiGer congress.

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