Gesture Production under Instructional Context: The Role of Mode of Instruction

Melda Coskun (MELDA.COSKUN@Metu.Edu.Tr)

Cengiz Acartürk (ACARTURK@Metu.Edu.Tr)

Cognitive Science Department, Informatics Institute
Middle East Technical University
06800, Ankara, Turkey

Abstract

We aim at examining how communication mode influences the production of gestures under specific contextual environments. Twenty-four participants were asked to present a topic of their choice under three instructional settings: a blackboard, paper-and-pencil, and a tablet. Participants' gestures were investigated in three groups: deictic gestures that point to entities, representational gestures that present picturable aspects of semantic content, and beat gestures that are speech-related rhythmic hand movements. The results indicated that gesture production of the participants was influenced by the mode of instruction (i.e., board, paper-and-pencil, tablet).

Keywords: Gesture production; Multimodal communication; Diagrams

Introduction

How gestures represent meaning has been subject to an interdisciplinary debate in the past decades (Acartürk & Alacam, 2012; Alibali & Nathan, 2007; Goldin-Meadow, Kim & Singer, 1999; Goldin-Meadow & Wagner, 2005; Rauscher, Krauss & Chen, 1996; Valenzeno, Alibali & Klatzky, 2003, among many others). Gestures have been proposed to enrich communication by supporting information in a second modality, usually conveying information that is not represented in speech. It has also been claimed that gestures promote communication by externalizing thoughts that are not formed well enough to express verbally (Alibali & Goldin-Meadow, 1993), thus reducing cognitive load of the speaker (Rauscher et al., 1996).

A frequently used ontology of gesture types is based on a threefold classification (McNeill, 1992): iconic and metaphoric gestures (henceforth, representational gestures), deictic gestures, and beat gestures. Beat gestures are merely speech-related rhythmic movements. They have not been a topic of intense research, since they have been conceived as substantial to the information content in communication. On the other hand, representational gestures and deictic gestures have been conceived as closely related to the information content of communication.

Deictic gestures are pointing movements of the arm or the fingers, which refer to concrete entities in the environment or refer to virtual entities that are not available in the environment but are subjects of communication. Deictic gestures have been proposed to construct a bridge between speech and the entity that is referred to by speech. Representational gestures, however, visualize *picturable aspects* of speech. Accordingly, representational gestures bear structural resemblance to what they represent.

Gestures and Diagrams

There is a close relationship between diagrams and gestures in terms of employing space and the spatial relations between mental representations of objects of interest during the course of communication. According to Tversky, Jamalian, Giardino, Kang, and Kessell (2013), gestures can be viewed as virtual diagrams in the air, whereas diagrams are the permanent traces of gestures on the surface. More generally, alongside language, gestures and diagrams may be conceived, as communication modalities that externalize common conceptual and spatial mental representations (Acartürk, 2010).

Gestures may represent meaning by sketching virtual diagrammatic elements in the air (e.g., lines, dots, boxes, arrows), as stated by Tversky, et al. (2013). In Heiser and Tversky (2004), the participants worked in pairs on a map to find the most efficient route to rescue a certain number of injuries. They produced gestures in a typical diagrammatic element form; pointing a place (e.g., dot), tracing a path between places (e.g., line), and tracing a place (e.g., box). In particular domains, gestures carry domain-dependent roles. For instance, gestures may highlight certain aspects of the information represented in time-series line graphs: a vertically oriented gesture may refer to an increase or a decrease, whereas a bidirectional horizontal gesture may refer to a durative state of the domain value (e.g., average temperature). In time-series bar graphs, directional gestures accompany verbal descriptions of trend information (Alacam, Habel, & Acartürk, 2013).

These findings suggest that gestures, like static diagrams, visualize thought by employing a set of content-free geometric forms. Diagrammatic entities such as dots, lines, boxes and arrows are basic content-free geometric forms, which represent meaning through geometric and gestalt properties. In both gestures and diagrams, these geometric forms refer to domain-specific entities.

Diagrams convey veridically (e.g., maps, architectural plans) or inherently (e.g., organizational charts, flows) the visible spatial relations by using diagrammatic constituents and the spatial relations between the constituents. The perpetual nature of diagrams allows them to represent information in conventional forms (Tversky et al., 2013), also by employing a wide range of perceptual processes, such as, compare; contrast; highlight similarity, distance, direction, shape, and size; rotate, group (Tversky, 2009).

Diagrams and gestures differ in their temporal characteristics. A major difference between gestures and diagrams is that gestures are momentary actions, whereas diagrams are relatively permanent visual representations. On the other hand, it is likely that the close relationship between diagrams and gestures is based on their common roots in cognitive sub-systems that are committed to processing spatial information. In the present study, we focus on gesture production in diagram-rich environments due to this close coupling between the two modalities.

Gestures and Diagrams in Context

In spite of the intense interest in gesture production in communication and its relation to linguistic utterances, the variability of contextual environments has attracted limited interest. The usual environment for gesture production has been a participant in a conversation. For example, McNeill's (1992) descriptions of gestures were contextualized in a dialogue environment, in which a participant produced spontaneous gestures in verbal communication. Similarly, Alibali (2005) employed a conversation as a contextual environment to describe the importance of gestures in daily communication, in which a man held two bags with his hands, needed to drop the bags and freed his hands when the conversation started.

The previous research on the interaction between language and gestures has made significant contribution to the study of human cognition. We propose that a further investigation of gesture production under specific contextual environments has the potential to contribute to cognitive science research. Moreover, it is not known whether the novel modes of communication (e.g., tablets and mobile phones) influence communication in positive or negative ways, by influencing gesture production More specifically, a question remains to be answered about whether the specific type of communication mode has any influence on gesture production.

In the present study, we investigate how communication mode influences the production of gestures under diagram-rich (thus, expectedly gesture-rich) instructional settings. For this, we employed three interfaces that allow sketching, as well as production of gestures:

- Board-and-boardmarker
- Paper-and-pencil
- Tablet-and-pen

In the rest of this paper, these interfaces will be shortly named *board*, *paper*, and *tablet* as three modes of instruction. The next section presents a broad overview of diagrams and gestures in instructional settings.

Diagrams and Gestures in Instructional Settings

Instructional settings are rich in diagrammatic representations. Diagrams are indispensable constituents in most instructional settings. Learning with multiple representations (i.e., diagrams and text) has been a major topic in cognitive science and related domains of research (e.g., Glenberg & Langston, 1992; Hegarty & Just, 1993; Hegarty, et al., 2005; Zahner & Corter, 2010), including instructional science (e.g., Gyselinck, et al., 2000; Mayer, 2009; Eitel & Scheiter, 2014, among many others). The findings mostly revealed a facilitating role of diagrams in learning. Accordingly, the research focus has been directed to the circumstances in which diagrams have those facilitating roles.

Previous research on gestures and learning has also revealed that nonverbal behavior might play a significant role in instructional settings (Kendon, 1980; McNeill, 1992). The studies have shown that teachers' nonverbal behavior might influence learning processes, for instance, by conveying teachers' attitude toward students. Gesture research in instructional science has a broad coverage of topics, from foreign language education (e.g., Sime, 2006) to mathematics education (Gerofsky, 2011). As a matter of fact, instructional science has been a major domain, in which gesture research has exhibited significant progress.

In the present study, we selected instructional setting as a contextual environment for our study due its richness both in the number and variety of diagrammatic representations and gestures. We also selected three modes of instruction, as described in detail below.

Experiment

Participants, Materials, and Design

Twenty-four content specialists, who had expertise content knowledge in math or science and were experienced in designing instructional products, (15 female, nine male) volunteered to participate in the study (mean age M = 30, SD = 3.7, age range was 25-38). The language of the experiment was Turkish and the participants were native Turkish speakers. Thirteen participants were experts in Math and 11 participants were experts in General Science.

The experiment design consisted of three within-subject conditions, namely the *mode of instruction*, as described in the previous section; board, paper, and tablet. Participants used whiteboard in the board condition, an A4-size paper in the paper condition, and a SMART Podium ID422w interactive pen display in the tablet condition (Figure 1).

Six groups were created by changing the order of these sessions in each group. This order was randomized across participants to counterbalance variance. The participants were randomly assigned to each group. Instructions were given to all participants before starting the experiment. None of the participants were aware of the aim of the study. They were told that it was investigated how different technologies affect learning and the sessions would be displayed by students later on, without providing any information about interest in gestures.

The participants were asked to select a topic and teach it as if there was a listener. They were also asked to the same topic in three sessions, namely board, paper and tablet. All the participants provided verbal informed consent for video recording during the sessions. Time was constrained to between 5 and 10 minutes for each session. The mean number of gestures was measured as a dependent variable.

Figure 1: The modes of instruction of the experiment. Explanation of equivalent fractions in the board (left), paper (middle) and tablet (right) session.

The participants selected topics from four subjects of Math and three subjects of General Science which were listed below[1]:

- Math:
  - Geometry (6)
  - Algebra-I (5)
  - Precalculus (1)
  - Trigonometry (1)
- Science:
  - Physics (4)
  - Chemistry (4)
  - Biology (3)

By the end of the experiment, 24 participants were recorded in three sessions and a total of 72 experiment protocols were obtained. ELAN (ELAN, 2013) was used for gesture and arrow annotations.

[1] The numbers in parentheses indicate the number of topics.

Gesture Annotation The speech-accompanying gestures were annotated following the methodology developed by Duncan (McNeill, 2005) based on the approach suggested by McNeill (1992, 2005). Gestures without speech were not included in the analysis. Type of gestures was determined based on the following descriptions (Figure 2):

- Representational Gesture: Gestures that presented *picturable* aspects of semantic content. Various aspects of gesture such as form, direction, motion trajectory of hand played a certain role in the depiction of semantic content (Alibali & Nathan, 2012).
  - Gestures that represented action or concept of a drawing or an object were assumed to be representational gestures. For example, the speaker's hand moved around a particle representation on the board to represent electric field.
  - Gestures that represented direction were accepted as representational gestures. For instance, in one part of the experiment the participant moved his hand forward while showing an upward palm to represent an outward direction.
- Deictic Gesture: Pointing movements that indicate physical, available objects, as well as physically unavailable ones at the time of gesturing. McNeill (1992) exemplifies deictic gestures which point unavailable entities with the following example: The speaker points to empty space to refer to a city rather than the physical space as he is asking to the listener where he came from before. In the present study, gestures that pointed a particular part or all parts of a diagram were annotated as deictic gestures.
  - The words referring to objects such as “this”, “here”, “there” were often accompanied by deictic gestures.
  - Gestures that traced a particular part or all parts of a drawing were assumed to be deictic gestures.
  - Gestures pointing a group of text, drawings or formulas were assumed to be deictic gestures. It created an impression on the audience that the speaker was indicating things inside a particular area the boundary of which was marked by the speaker’s hand movements.
  - Deictic gestures were typically performed with the extended finger or hand in the board session whereas they were mostly produced by the pen in paper and tablet sessions.
- Beat Gesture: Speech-related rhythmic hand movements. In the present study, following the literature (McNeill, 1992), beats were divided into two forms; discrete and continuous. Beat gestures in discrete form were produced when a syllable, word or clause was stressed and disappeared right after the utterance. Beat gestures in continuous form were produced throughout speech (word, clause, and sentence). They often occurred in a series of a

particular hand movement. Circular, continuous movement of hand could be an example for a beat gesture in continuous form.

Figure 2: A representational gesture illustrating "pull and push " action (left), a deictic gesture pointing to the particle on the table (middle), a beat gesture which is a speech-related rhythmic movement (right).

All the gesture annotations were initially performed by the first author of study. Randomly-selected 25% of the all gestures (880 of 3523) were annotated independently by a second coder who was aware of the aim of the study, for reliability analysis. Both coders were native Turkish speakers and they annotated the participants' gestures and arrows by listening and watching their recordings. The comprehension of the participants' utterances also played role in the annotation. Cohen's kappa was used to calculate inter-rater reliability between coders. The inter-rater agreements of initial annotations were calculated as .75. The value above .61 indicates substantial inter-rater agreement and the value between .81 and .99 indicates almost perfect agreement based on Landis and Koch (1977). Upon discussion the coders re-annotated the gesture data and the agreement was calculated as .96.

Results

Teaching Duration. A one-way within-subjects ANOVA was conducted to evaluate a significant difference in the duration of the teaching sessions. A comparison of the mean durations (in minutes) among the tablet condition ($M = 6.8$, SD = 2.29) the board condition ($M = 6.5$, SD = 2.22) and the paper condition ($M = 6.0$, SD = 2.11) revealed no significant difference, Wilk's $\lambda = .82$, $F(2, 22) = 2.4$, $p = .11$.

This result indicates that teaching duration was not affected by the instructional mode conditions. Therefore, it was not included in the further analyses.

Mean Number of Gestures. The mean number of gestures were analyzed under the three modes of instruction and three types of gestures. The analysis revealed the results shown in Table 1.

Table 1: The mean number of gestures (standard deviations) for subtypes of gestures

	Deictic	Beat	Representational
Board	31.25 (13.58)	20.79 (20.16)	3.54 (3.71)
Paper	29.92 (16.22)	17.00 (14.55)	2.13 (2.19)
Tablet	26.75 (11.63)	14.38 (10.03)	1.13 (1.22)

Note Zero values were included in the analysis. The numbers in parentheses indicate Standard Deviation

A three-way within-subjects ANOVA was conducted to evaluate the effect of the instructional mode on the mean number of gestures. Main effects and interaction effects were tested for the *mode of instruction* (board, paper, tablet) and the *gesture type* (deictic, representational, beat) using multivariate criterion of Wilk's lambda (λ). A significant main effect was obtained for the mode of instruction, $\lambda = .37$, $F(2, 22) = 6.44$, $p < .05$, as well as for gesture type, $\lambda = .86$, $F(2, 22) = 69.40$, $p < .05$. However, the interaction was not significant.

Three paired-samples *t* tests were conducted to compare the mean number of gestures among the conditions, controlling for familywise error rate using Holm's sequential Bonferroni approach. Gestures were significantly higher in the board condition compared to the tablet condition, $t\ (23) = 3.66$, $p < .05$. However, there was no significant difference between the paper condition and the tablet condition, $t\ (23) = 1.67$, $p = .11$ in the number of gestures. The difference between the board condition and the paper condition was also not significant, $t\ (23) = 1.75$ $p = .09$.

Three paired-samples *t* tests were conducted to compare the number of gestures types, controlling for familywise error rate using Holm's sequential Bonferroni approach. The mean number of deictic gestures was significantly higher compared to representational gestures, $t\ (23) = 11.47$, $p < .05$, and beat gestures, $t(23) = 3.86$, $p < .05$. The mean number of beat gestures was significantly higher than representational gestures, $t\ (23) = 5.97$, $p < .05$.

Discussion

The results of the experimental investigation revealed that gesture production patterns of the participants were influenced by the contextual environment (in this case, the mode of instruction). In particular, the participants produced more gestures when they used a board-and-boardmarker (in a standing position), compared to the instructional context, in which they used a tablet or paper-and-pencil (both in a sitting position). There are at least two likely sources of the findings about the mode of communication, as described below.

The first is conventional vs. non-conventional modes of communication. All the participants of the experiment were expert educators, for whom the most frequently used type of instructional setting was the blackboard setting during their previous education. The other two modes, namely paper and tablet, are not as frequent as the board setting as a mode of communication currently. This aspect of instructional settings may change by technological advances in future.

The second likely source of more-frequent gesture production in the board setting is that the board setting has a different physical configuration than the paper-and-pencil setting and the tablet setting, in terms of participants' position during the task (standing vs. sitting). The board condition allows participants to control their bodily postures and to produce arm gestures more freely. In other words, in the standing position, the speakers may include their body posture in a conversation more freely compared to the sitting positions. The sitting positions may restrict the hands of a speaker from engaging in a conversation. Moreover, the possibility of a having technical problem (e.g., touching an irrelevant location on the tablet screen) might have resulted discomfort on the speakers' side, which resulted in limited number of gestures hand movements in the tablet setting. Taking into account the facilitating role of gestures in learning, these findings reveal an important advantage in favor of the classical blackboard instructional setting over the more recent tablet setting.

In terms of the number of gestures, gesture production also exhibited significant differences among sub-types: Deictic gesture was the most frequently produced gesture. Participants produced significantly higher number of deictic gestures than both representational gestures and beat gestures. Representational gestures were the least produced gesture type. These findings show that the deictic function of gestures in the instructional context had a much larger role than its representational function in the present study. A likely reason for this finding is that the settings consisted of boardmarkers and pens; hence, the speakers preferred to visualize their thoughts in a concrete way by sketching instead of producing representational gestures. It is also likely that the *picturable* aspects of the content were limited, which might have resulted in much less number of representational gestures than deictic gestures. As a consequence, a comparison between the two gestures types in terms of their frequency of production may be misleading, when one generalizes the findings obtained in the present study to other contextual environments. A more-constrained experiment design, which controls the spatial content of the stimuli, would better address the role of deictic vs. representational gestures in different contextual environments.

Conclusion and Future Work

Gestures are an integrated part of speech. The relationship between verbal and nonverbal communication modalities, such as the relationship between language and gestures, and language and diagrams have been the topic of intense research since the past several decades. Further research is needed to extend research on multimodal communication, by focusing on relationship between nonverbal modalities (Flevares & Perry, 2001), as well as the production of gestures under specific contextual environments. The present study aimed at addressing and filling this gap in the literature, by focusing on how the mode of instruction (board, paper and tablet) influences gesture production. The results reveal differences in gesture production among these three modes of instruction. In particular, deictic gestures are more frequent compared to representational gestures. Moreover, board is a more appropriate environment for allowing gestures, both in terms of their number and variety.

In future work, we plan to address the limitations in the present study, which were mostly due to difficulties in setting up a more realistic experiment environment: The participants were asked as if they made their presentation to a classroom audience. A real classroom setting would influence the gesture production patterns.

We also conjecture that future intrusion of tablet use in daily life may result in changes in gesture patterns in tablets. Finally, we conceived gesture production as a domain-dependent. action in the present study The specific domain of discourse (e.g., topics geometry or physics) , depending on its semantic richness in spatial terms, may influence production of different gesture types.

Acknowledgements: This work was partially funded by Marie Curie Actions IRIS (ref. 610986, FP7-PEOPLE-2013-IAPP) and METU Scientific Research Project scheme BAP–08-11-2012-121 Investigation of Cognitive Processes in Multimodal Communication. Thanks SEBIT Inc. for technical support during data collection. Thanks our reviewers for their useful comments and suggestions.

References

Acartürk, C. (2010). *Multimodal comprehension of graph-text constellations: An information processing perspective*. Unpublished dissertation, University of Hamburg.

Acartürk, C., & Alacam, O. (2012). Gestures in communication through line graphs. In N. Miyake, D. Peebles & R. P. Cooper (Eds.), *Proceedings of the 34th Annual Conference of the Cognitive Science Society*. (pp. 66-71). Austin, TX: Cognitive Science Society.

Alacam, Ö., Habel, C., Acartürk, C. (2013). Gesture and Language Production in Communication through Bar Graphs. In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society* (pp. 1714-1719). Austin, TX: Cognitive Science Society.

Alibali, M. W., & Goldin-Meadow, S. (1993). Gesture-Speech Mismatch and Mechanisms of Learning: What the Hands Reveal about a Child's State of Mind. *Cognitive Psychology*, 25, 468-523.

Alibali, M. W. (2005). Gesture in Spatial Cognition: Expressing, Communicating, and Thinking About Spatial Information. *Spatial Cognition & Computation*, 5(4), 307-331.

Alibali, M. W., & Nathan, M. J. (2007). Teachers' gestures as a means of scaffolding students' understanding: Evidence from an early algebra lesson. *Video research in the learning sciences*, 349-365.

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in Mathematics Teaching and Learning: Evidence From Learners' and Teachers' Gestures. *Journal of the Learning Sciences*, 21(2), 247-286.

Eitel, A., & Scheiter, K. (2014). Picture or text first? Explaining sequence effects when learning with pictures and text. *Educational Psychology Review, 27*(1), 153.180. doi 10.1007/s10648-014-9264-4.

ELAN (Version 4.6.2) [Computer software]. (2013) Retrieved from http://tla.mpi.nl/tools/tla-tools/elan/. Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands.

Flevares, L. M., & Perry, M. (2001). How many do you see? The use of nonspoken representations in first-grade mathematics lessons. *Journal of Educational Psychology*, 93(2), 330-345.

Gerofsky, S. (2011). Mathematical learning and gesture: Character viewpoint and observer viewpoint in students' gestured graphs of functions. *Gesture, 10*(2-3), 321-343.

Glenberg, A. M., & Langston, W. E. (1992). Comprehension of illustrated text: Pictures help to build mental models. *Journal of Memory and Language*, 31, 129-151.

Goldin-Meadow, S., Kim, S., & Singer, M. (1999). What The Teacher's Hands Tell The Student's Mind About Math. *Journal of Educational Psychology,* 91(4), 720-730.

Goldin-Meadow, S., & Wagner, S. (2005). How Our Hands Help Us Learn. *Trends in Cognitive Sciences*, 9(5), 234-241.

Gyselinck, V., Ehrlich, M. F., Cornoldi, C., De Beni, R., & Dubois, V. (2000). Visuospatial working memory in learning from multimedia system. *Journal of Computer Assisted Learning*, 16, 166–176.

Hegarty, M., & Just, M. A. (1993). Constructing mental models of machines from text and diagrams. *Journal of Memory and Language*, 32, 717-742.

Hegarty, M., Mayer, S., Kriz, S., Keehner, M. (2005). The role of gestures in mental animation. *Spatial Cognition and Computation*, 5, 333-356.

Heiser, J. & Tversky, B. (2004). Characterizing diagrams produced by individuals and dyads. In T. Barkowsky (Editor). *Spatial cognition: Reasoning, action, interaction*. Pp. 214-223. Berlin: Springer-Verlag.

Kendon, A. (1980). Gesticulation and speech: Two aspects of the process of utterance. *The Relationship of verbal and nonverbal communication*. Pp. 207-227. The Hague: Mouton.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 159-174.

Lausberg, H., & Sloetjes, H. (2009). Coding gestural behavior with the NEUROGES-ELAN system. Behavior Research Methods, Instruments, & Computers, 41(3), 841-849. doi:10.3758/BRM.41.3.591.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge: Cambridge University Press.

McNeill, D. (1992). *Hand and Mind: What gestures reveal about thought.* Chicago: University of Chicago Press.

McNeill, D. (2005). *Gesture and thought.* Chicago: University of Chicago Press.

Rauscher, F. H., Krauss, R. M., & Chen, Y. (1996). Gesture, Speech, and Lexical Access: The Role Of Lexical Movements In Speech Production. *Psychological Science*, 7(4), 226-231.

Sime, D. (2006). What do learners make of teachers' gestures in the language classroom? *Review of Applied Linguistics in Language Teaching, 44*(2), 211-230.

Tversky, B. (2001). Spatial schemas in depictions. *In Spatial schemas and abstract thought*, 79-111.

Tversky, B., Jamalian. A., Giardino. V., Kang. S., Kessell. A., (2013). Comparing Gestures And Diagrams. In *Online Proceedings of TiGeR 2013: The combined meeting of the 10th international Gesture Workshop (GW) and the 3rd Gesture and Speech in Interaction (GESPIN) conference.*

Tversky, B. (2009). Spatial cognition: Embodied and situated. In *The Cambridge handbook of situated cognition* (pp. 201-217). Cambridge: Cambridge University Press.

Valenzeno, L., Alibali, M. W., & Klatzky, R. (2003). Teachers’ gestures facilitate students’ learning: A lesson in symmetry. *Contemporary Educational Psychology*, 28(2), 187-204.

Zahner, D. C., & Corter, J. E. (2010). The process of probability problem solving: Use of external visual representations. *Mathematical Thinking and Learning, 12*(2), 177-204.