Statistical line graphs are widely used in various multimodal communication settings. For visually impaired people, haptic-audio interfaces may effectively substitute visual graphs by providing perceptual access to graphical representations. Graphs do not only present data \textit{(first order entities)} but also allow the extraction of \textit{second order entities} (such as extreme values, trends, or changes of trends). In a series of studies, we investigated referring expressions used in a collaborative joint activity between haptic explorers (blind-folded sighted people) who explore graphs haptically and verbal assistants who help haptic graph readers to conceptualize local and non-local second-order concepts. These studies provide the empirical basis for our long-term goal: the realization of a cooperative system providing blind graph readers with verbal assistance (Acartürk, Alacam & Habel, 2014).

Blind people can explore haptic graphs using—for example—a stylus of a force-feedback device (e.g., a Phantom Omni®, recently Geomagic® Touch$^\text{TM}$), which yields information about geometrical properties of lines. Comprehension of haptic line graphs is based on explorations processes, i.e. hand movements tracing lines, which aim at detecting shape properties of the graph line explored (see Fig.1 for a sample line graph). Verbally assisted haptic graph exploration can be seen as a task-oriented collaborative activity between two partners, a (visually impaired) explorer (E) of a haptic graph and an observing assistant (A) providing verbal assistance (see Figure 2).

![Image](https://via.placeholder.com/150)

**Figure 1.** Qualitative shape landmark ascription for a sample graph

![Image](https://via.placeholder.com/150)

**Figure 2.** Assisted haptic graph exploration, a joint activity

The participants in this joint activity have different activity roles (explorer vs. assistant), as well as different sensory abilities. In the present study we focus on the participant’s different preferences for the use of reference frames. Despite different perceptual modalities (haptic versus visual), both E and A have access to an absolute frame of the graph and its axes (spatial-perspective). Statistical line graphs with a left-to-right directed-line are not just spatial representations; their meanings emerge from combining temporal and spatial aspects in a “spatiotemporal-perspective”. Haptic explorers’ spatial reference frames are mostly induced by their hand movements (action-perspective). In case of ‘backward explorations’ (from right-to-left) this can lead to ‘unusual’ (‘misinterpreting’) referring expressions, e.g., a ‘decrease of the graph line’ may be expressed as an ‘increase’ in backward perspective (see “sp3-sp2” line segment in Figure 1). On the other hand, the observers also have visual access to the movement-induced frame (of the explorers). It should be also noted that simultaneous visual exposure to all graphical elements seems to trigger spatiotemporal perspective that yields graph domain descriptions.

In the experiment, 13 participant pairs (E and A, $M_{age}=25.3$, $SD=3.27$) collaborated in exploring haptic line graphs. Haptic explorers were presented the stimuli, which
included seven line graphs. The participants were informed that they were presented bird-population graphs. An assistant provided verbal assistance to the haptic explorer during the course of haptic exploration when it was requested. We classified the utterances produced during the joint activities (1588 individual utterances in total) into three categories:  

1. Request-Response Pairs (63.9% of all utterances),  
2. Alerts initiated by A (5.9%) and  
3. Think-aloud sentences (30.2%).

Six of 13 haptic explorers produced utterances that indicated clear cases of the above-mentioned ‘misinterpreting descriptions’ during right-to-left reading, and these utterances were mostly observed during self-talking in exploring of the first two graphs, considered as a familiarization phase. After one or two graphs, all haptic explorers who exhibit “unusual” reading gained sensitivity to overcome movement-induced action-perspective (Beveridge & Pickering, 2013): they use graph-domain spatiotemporal perspective, and switch between them when necessary. Later on, when the explorers perform backward graph reading, they tend to use terms without direction, or temporal information (such as referring to the segments by “fluctuations”, or counting of the salient landmarks). Moreover, explorers are also inclined to skip explaining the graph during backward-motion and start again when they reach the beginning of the graph or segment, indicating that spatiotemporal perspective interferes with action-perspective during the course of haptic exploration.

Another factor in perspective taking is the communicational goal of the utterances: navigational, focusing on the graph to be explored, vs. descriptional, considering the content about a domain, e.g. ‘bird population’. When the explorer uses the action-perspective, instructional expressions (such as “you are going up”) seem dominant. On the other hand, if the utterance involves descriptional content about the graph domain, then expressions using the spatiotemporal-perspective (such as “it increases”) were observed. In both cases, observing assistants tend to lessen the explorers’ burden for aligning by using explorer’s perspective.

To sum up, haptic explorers’ first preference is to focus on basic spatial properties of the graphs by employing action-perspective. However, when they realize that it may not be sufficient to explain changes in graph domain or it may conflict with graph reading, they switch to spatiotemporal-perspective, which is more relevant for highlighting the changes in the population that the graph represented. Additionally, the result of the experiment showed that a given action is being simulated from the exploring agent’s perspective (action-perspective: Beveridge & Pickering, 2013). The verbal assistance system should align itself to explorer’s current perspective for the sake of the communication; however the explorer’s perspective is not always the most efficient perspective for the conceptualization of the graph, therefore the referring expressions should be produced by taking this gap into account. These findings are highly relevant for designing an NLG system that produces adequate referring expressions for verbal assistance and for aligning the interlocutors’ internal models (Garrod & Pickering, 2004) during verbally assisted graph exploration.

REFERENCES

1 The term ‘utterance’ refers to speech parts produced coherently and individually by each participant.