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ARTICLE

Moving meetings by moving gesture and prosody

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Abstract
In English, asking the question 'Next Wednesday's meeting has been moved forward two days, on what day is it now?' has two possible answers, with past research suggesting that about half of all people respond 'Monday', and about half respond 'Friday'. Past research has shown that producing directional gestures can help resolve this ambiguity: when the speaker gestures away from themselves, the proportion of 'Friday' responses increases, compared to gesturing toward themselves. Here, we use this established fact to investigate the impact of the relative coordination of gestural, verbal and prosodic elements. Across three experiments, we find that disambiguation is strongest when gestures coordinate with the adverb 'forward' as opposed to the verb 'moved'. Furthermore, when orthogonalizing the coordination of gestures and pitch accents, we show that disambiguation is more strongly influenced by semantic as opposed to prosodic factors. We outline implications for different theories on the semantic integration of speech and gesture.

Keywords: gestures; metaphor; multimodality; pitch accents; synchrony

1. Introduction

Gesture contributes meaning to spoken utterances. Sometimes this contribution is supplementary, as when a speaker says 'I wrote a letter' while producing a typing gesture (Obermeier et al., 2011); other times it is central, such as when a speaker says 'This one' while pointing at an object. Production studies show that speakers use gestures to disambiguate homonyms (Holler & Beattie, 2003), and perception studies show that such gestures are used to infer the intended meaning (Holle & Gunter, 2007).

What is known as the Next Wednesday Question (NWQ) provides one of the clearest demonstrations of the disambiguating power of gesture. When presented in a written version, the question 'Next Wednesday's meeting has been moved forward two days, on what day is it now?' is ambiguous and elicits both 'Monday' and 'Friday'

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responses (McGlone & Harding, 1998). The ambiguity arises because the spatial adverb *forward* can either be interpreted from an ego-moving perspective, analogous to 'We are approaching the meeting', or a time-moving perspective, analogous to 'The meeting is approaching us' (Clark, 1973; Moore, 2006; Nuñez et al., 2006). Across studies, about half of all participants favor each interpretation (Stickles & Lewis, 2018), although substantial individual differences have been documented (Duffy & Feist, 2014; Duffy et al., 2014; Feist & Duffy, 2023; Li, 2024; Li & Cao, 2021), and results may be more or less biased toward either 'Monday' or 'Friday' responses depending on the precise way the question is formulated (Feist & Duffy, 2015). Figure 1 illustrates the underlying concept of the ego-moving and time-moving perspectives in the NWQ paradigm.

Previous research has shown that the ego-moving/time-moving ambiguity of the NWQ can be partially resolved by gesture. Jamalian and Tversky (2012) demonstrated that a sagittal gesture directed away from the speaker substantially increases the proportion of 'Friday' responses, and vice versa, a gesture directed toward the speaker increases the proportion of 'Monday' responses. This finding has subsequently been replicated numerous times (Lewis & Stickles, 2017; Tversky & Jamalian, 2021; Winter & Duffy, 2020). The effect size is substantial: although never reaching 100% 'Monday'/'Friday' responses with *all* participants, the gesture can shift responses from near-full ambiguity (at the population level: 50%) to roughly 80% 'Monday' or 80% 'Friday' responses.

Now that we know that gesture matters in resolving the perspectival ambiguity of the NWQ, we can ask new questions. The NWQ provides an ideal test case because a directional gesture could plausibly relate both to the motion event encoded by 'moved' and to the directional adverb 'forward'. The question is no longer whether gesture matters in this task, but *when* and *where* gesture is integrated with speech. In this study, we use the NWQ as a test bed for studying how the coordination of gestural, verbal and prosodic elements impacts semantic integration, and ultimately ambiguity resolution. Rather than asking whether gesture influences interpretation,

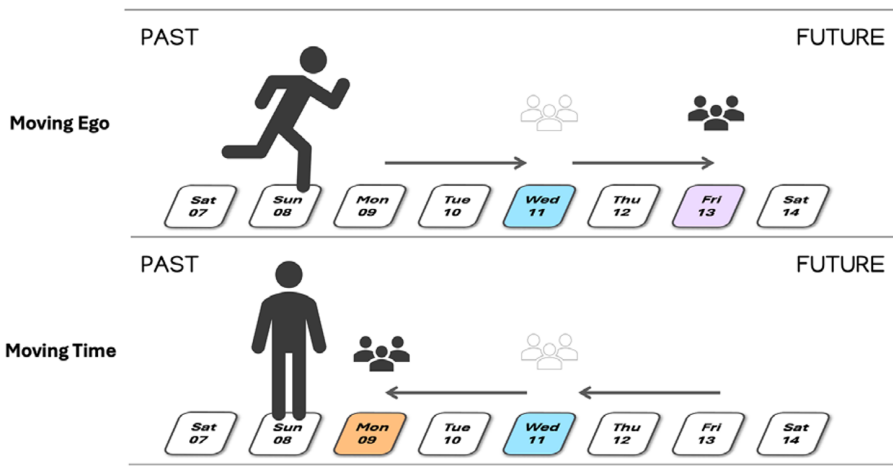


Figure 1. Schematic illustration of the ego-moving and time-moving perspectives.

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we can ask how gesture is integrated with the prosodic and verbal dimensions of the NWQ, and how this depends on the relative timing of different elements with respect to each other.

2. Background

Except for emblems, which are highly conventionalized gestures such as 'thumbs up', gesture meaning is rarely interpreted independently of concomitant spoken language. Most co-speech gestures are semantically dependent on accompanying speech (Kendon, 2015). Experiments demonstrate that while emblems can often be understood in isolation (Gunter & Bach, 2004), iconic gestures are typically underspecified without linguistic context (Feyereisen et al., 1988; Hadar & Pinchas-Zamir, 2004; Krauss et al., 1991). A circular hand movement, for example, could refer to any round object, a circular path, or a cycle, among many other things. When the movement is combined with 'We did it again', however, it becomes clear that it signals repetition.

This dependence of gesture on speech has also been demonstrated in the NWQ paradigm. Winter and Duffy (2020) found that replacing 'moved' with 'changed by' eradicated any effect of gesture, i.e., sagittal forward and backwards movements did not meaningfully affect the proportion of 'Monday' or 'Friday' responses. They argued that when speech no longer evokes movement, listeners are less likely to interpret the gesture as depicting motion along a timeline. More generally, the evidence that gesture influences the interpretation of spoken utterances (Beattie & Shovelton, 1999; Graham & Argyle, 1975; Holle & Gunter, 2007; Kelly et al., 1999; McNeill et al., 1994) and that spoken utterances influence the interpretation of gestures (Hadar & Pinchas-Zamir, 2004; Krauss et al., 1991) shows that speech and gesture interact by mutually constraining one another during meaning construction (Cassell et al., 1999; Kelly et al., 2010, 2015).

This process of semantic integration fundamentally depends on the temporal coordination of speech and gesture: successful integration is strongest when gestures overlap with, or slightly precede, the corresponding verbal element (Habets et al., 2011; Obermeier et al., 2011). This mirrors production patterns, where gesture strokes are tightly synchronized – usually partially overlapping or slightly preceding – with the semantically related element in speech (Butterworth & Beattie, 1978; Kendon, 1980; Leonard & Cummins, 2011; McNeill, 1992; Morrel-Samuels & Krauss, 1992). However, the NWQ presents multiple potential candidates for such integration. A directional gesture could plausibly relate to the motion event encoded by the verb 'moved', or the directional information encoded by the adverb 'forward'. Determining which of these elements serves as the primary anchor for gesture interpretation in the NWQ is a central goal of this study (Experiments 1–3).

A further goal is to test how this temporal coordination interacts with prosody. Gestural and prosodic prominences are closely coordinated in production (Esteve-Gibert & Prieto, 2013; Fung & Mok, 2018; Jannedy & Mendoza-Denton, 2005; Loehr, 2012; for review, see Wagner et al., 2014). However, previous gesture studies on the NWQ either did not report how stimuli were realized prosodically (Jamalian & Tversky, 2012; Lewis & Stickles, 2017; Tversky & Jamalian, 2021), or did not systematically manipulate prosody (Winter & Duffy, 2020). This raises the possibility that the effect of gesture on ambiguity resolution may not only depend on semantic affiliation, but also on alignment with prosodic prominence; e.g., it could make a

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great difference to how the NWQ is interpreted if the primary pitch accent of the sentence is placed on the verb 'moved' or the adverb 'forward'. We therefore investigate both dimensions simultaneously (Experiment 3).

3. Different accounts of gesture integration in the NWQ

Across three experiments, we manipulated the temporal alignment of gesture, speech and prosody. In our conditions, gestures either coincided with the verb 'moved', coincided with the spatial adverb 'forward' or occurred after the target sentence containing the primary directional information ('Next Wednesday's meeting has been moved forward two days [**gesture**]. On what day is it now?') has been completed (post-target; Experiments 1–2). In Experiment 3, we additionally manipulated whether the primary pitch accent of the sentence falls on the verb or the adverb.

We designed and conducted the experiments in sequence. In Experiment 1, the gesture-on-adverb condition necessarily included the adverb, but the NWQ in the verb and post-speech conditions excluded the adverb. After realizing that the baseline probability of responding Friday, regardless of gesture direction, was much higher for both conditions without the adverb, we realized that leaving out the adverb fundamentally changes the nature of the NWQ from a genuine ambiguity to complete underspecification. The effect of gesture placement cannot be interpreted independently of the presence of the adverb 'forward' – without this adverb, direction is not a meaningful part of the question at all. To deconfound gesture placement and adverb presence, Experiment 2 filled in the missing gesture-on-verb and post-speech conditions that also included the adverb. This means that taken together, Experiments 1 and 2 allow us to disentangle the relative contributions of gesture placement and adverb presence. Experiment 3 then proceeded with investigating gesture placements with pitch accents using a version of the NWQ that always included the adverb.

As discussed in this section, these manipulations across Experiments 1–3 allow us to test different accounts of gesture integration, which we dub 1) adverb anchoring, 2) verb anchoring, 3) gesture priming, 4) gesture salience and 5) prosodic anchoring. These accounts are introduced below.

3.1. Adverb anchoring

A first possibility is that gesture is primarily integrated with the element that is directly implicated in the ambiguity of the NWQ, the adverb 'forward'. The spatial ambiguity inherent in the NWQ is most closely related to whether 'forward' is interpreted as moving forward in an ego-moving manner (away from speaker) or a time-moving manner (toward speaker). Indeed, Winter and Duffy (2020) and Lewis and Stickles (2017) seem to have tacitly assumed that the spatial adverb would be the most relevant gestural anchor by coordinating their directional gestures with this element (Jamalian & Tversky, 2012 and Tversky & Jamalian, 2021 conducted their experiments face-to-face and spoke of alignment with the entire verb phrase, leaving it open where the gesture was placed exactly). If directional information is indeed the key integration point, gesture should have its strongest influence with 'forward'. The effect of forward/backward gestures should weaken when gestures are shifted to the verb, or to the post-target position following the question.

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3.2. Verb anchoring

A second possibility is that gesture is integrated with the primary motion event described by the sentence, i.e., the verb. Production studies find gestures to be most common with verbs (Hadar & Krauss, 1999; Wilding et al., 2025). Close alignment between the directional gesture and the verb is also expected under the Gesture-as-Simulated-Action framework (Hostetter & Alibali, 2008, 2019), which views gestures as externalized motor simulations of actions and events. Applied to the NWQ, this account leads us to expect that the verb 'moved' constitutes the primary integration point: because the gesture depicts movement, it should have the strongest influence when aligned with the verb rather than the adverb. The post-target gesture condition should have the weakest effect because here, the gesture follows the entire sentence and is therefore outside of the verb phrase.

3.3. Gesture priming

A third possibility is that earlier elements bias the understanding of later elements, i.e., gesture influences interpretation through a priming mechanism where the spatial direction implied by the gesture influences how following elements are understood. Previous work has shown that gestures can prime semantically related concepts (So et al., 2013; Vainiger et al., 2014; Wu & Coulson, 2005, 2007; Yap et al., 2011). The idea that priming matters is also suggested by previous work on the NWQ itself. Boroditsky (2000) and following this, many other studies (e.g., Boroditsky & Ramscar, 2002; Matlock et al., 2005; Sullivan & Barth, 2012) found that spatial primes, such as images showing forward movement versus images of pulling something toward oneself, prime ego-moving and time-moving perspectives when hearing the NWQ, as shown by a relative difference in 'Monday'/'Friday' proportions between these priming conditions. From the perspective of our current study, the directional gestures might behave just like the spatial primes used in these experiments. Since our experiment does not feature a gesture preceding the NWQ, our experiment is not set up to differentiate gesture priming from verb anchoring. Both lead us to expect that gesture effects are strongest on the verb condition, weaker on the adverb and weakest in the post-target condition.

3.4. Gesture salience

A fourth possibility focuses on how salient a gesture is. What makes a gesture salient is presumably influenced by many different factors such as a gesture's size and velocity, whether unusual hand shapes are used and so forth. One dimension of salience that we can easily manipulate in a way that is analogous to the verb/adverb placement is to have a gesture occur on its own. This is analogous to Ebert and Ebert (2014) and Schlenker (2018), who analyze co-speech gestures as conveying meaning that is less central to a message than post-speech gestures (for review, see Ebert, 2024). An account rooted in gesture salience would predict that a directional gesture following the NWQ would have the strongest impact on 'Monday'/'Friday' responses because it stands out as an independent communicative signal.

3.5. Prosodic anchoring

The fifth and final possibility is that semantic integration depends on alignment with prosodic prominence. Because pitch accents signal prominence (Baumann & Röhr, 2015;

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Baumann & Winter, 2018; Terken & Hermes, 2000; Turnbull et al., 2017 for a review), listeners may attend more strongly to gestures that coincide with accented elements. Extensive research in production shows that gestures have a strong probabilistic tendency to occur together with pitch accents or other prosodically prominent elements (Baills & Baumann, 2025; Esteve-Gibert & Prieto, 2013; Fung & Mok, 2018; Gregori & Kügler, 2026; Im & Baumann, 2020; Jannedy & Mendoza-Denton, 2005; Loehr, 2012; Türk & Calhoun, 2024; for an early review, see Wagner et al., 2014). If prosodic anchoring matters, we would expect forward/backward gestures to influence 'Monday'/'Friday' responses when gestures coincide with the accented constituent, regardless of whether this constituent is the verb or the adverb. Experiment 3 crosses gesture placement (on verb, on adverb) with pitch accent placement (on verb, on adverb). In this 2 × 2 design, if the prosodic anchor were the key point for semantic integration, we would predict a match effect, i.e., an interaction between gesture position and pitch accent position.

Table 1 summarizes the predictions of the different accounts. Experiments 1 and 2 include a post-target condition and allow us to test the first four possibilities. Experiment 3 is set up to specifically test the contribution of prosody, but by virtue of having two gesture placement conditions (verb, adverb), it also provides converging evidence for the relative contribution of these elements.

3.6. Additional factors: gesture awareness and likeability

Across our experiments, we also asked whether participants were aware of the gesture, i.e., whether they consciously noticed them. If the gesture was indeed more salient in the post-target condition, participants should be more aware of it. The effect of the forward/backward gesture may overall be stronger for participants who consciously noticed the gesture.

In the very first gesture study on gestures in the NWQ, Jamalian and Tversky (2012) asked participants the question while producing forward/backward gestures standing next to the participant. This disambiguates another dimension of perspective, not temporal perspective (ego-moving vs. time-moving), but whether the participant takes the speaker's orientation with respect to gesture in general. When looking at the gesturer face-to-face, a speaker's forward gesture is actually a movement *toward* the listener. This means that a participant assuming the speaker's perspective should resolve the ambiguity toward 'Friday', and a participant *not* assuming their perspective should resolve it toward 'Monday'. Whether participants take the speaker's perspective is thus a latent factor that potentially weakens gestural effects when conducting the experiment online with video stimuli where the gesture cannot be produced standing next to the speaker, as in Jamalian and Tversky (2012).

Table 1. Expectations about the influence of gesture on 'Monday'/'Friday' responses for different accounts of semantic integration in the NWQ

Account	Proposed integration point	Expectation
Adverb anchoring	Spatial adverb 'forward'	Adverb > verb > post-target
Verb anchoring	Verb 'moved'	Verb > adverb > post-target
Gesture priming	Earlier gesture biases later interpretation	Verb > adverb > post-target
Gesture salience	Independent post-speech gesture	Post-target > adverb ≈ verb
Prosodic anchoring	Alignment with pitch accent	Match > mismatch

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One way of probing this latent factor is via likeability, with the linking assumption that participants would be more willing to take the speaker's perspective if they like them. This linking assumption was motivated by the results of an open-ended post-experiment debriefing question reported in Winter and Duffy (2020) (Experiment 1), which showed that participants spontaneously reported very strong (dis)preferences for the speaker seen in the video stimulus. To address this possible latent factor, Winter and Duffy (2020) included a standard likeability scale (Reysen, 2005) in their Experiments 2–4. Results showed that within each experiment, the impact of likeability on the influence of directional gestures was too subtle to pass conventional thresholds of certainty, but when entered into a combined analysis, there was enough evidence for a small but consistent effect: speakers who liked the model seen in the video more were relatively more strongly affected by gestural direction. In this study, all three experiments include a questionnaire item on likeability. This allows us to assess whether this element of Winter and Duff's study (2020) replicates.

4. Methods

As all three experiments use the same general question and gestures, we introduce their methods together.

4.1. Procedure

We used the online questionnaire SoSci Survey (Leiner, 2021) to collect responses to the NWQ in three pre-registered experiments in a between-participants single-trial design. The pre-registration of all studies can be found on OSF: https://osf.io/p8svw/overview.

After consenting, participants first performed a test to see whether their audio and video worked. After this, they answered three demographic questions: age, gender and which languages they spoke. After a simple attention check (15 + 7 =?), participants read the following instructions before the main trial:

> On the next screen, you will see a video of a person asking a question. Focus on the screen and listen to what the person has to say. Please play the video only once and respond quickly and intuitively with whatever comes to mind first. Try to not overthink and do not change your answer: we are interested in your initial reaction.

After clicking continue, participants saw a video of a speaker producing different versions of the NWQ (see Stimuli in Section 4.2). They then entered their response into an open-ended text entry box that was displayed beneath the video on the same page. We also asked whether participants were consciously aware of the gesture, and whether they learned best with visual, auditory or haptic input (this dimension was not analyzed in the current study). In addition, they rated how much they liked the speaker on a scale from 1 to 7 in Experiment 1 (see Winter & Duffy, 2020). In Experiments 2 and 3, the simple one-dimensional likeability question was replaced by four questions from the Reysen likeability scale (Reysen, 2005), for which participants were asked whether they found the speaker in the video likeable, approachable, warm and friendly. For Experiments 2 and 3, we also added an open-ended entry box where participants could enter their thoughts on the experiment and give feedback.

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The data collection for all experiments was performed on a Wednesday, as has been done in the original experiment by McGlone and Harding (1998) and because Winter and Duffy (2020) found a day-of-the-week effect, where participants responded 'Friday' or 'Monday' more often the closer the day of testing was to either one of these days.

4.2. Stimuli

Across all experiments, we used the following formulation of the NWQ: 'Next Wednesday's meeting has been moved (forward) two days. On what day is it now?' This question was asked by a female British English native speaker and always paired with a gesture, which across all conditions was a one-handed 'flat wall' handshape that was moved along the sagittal plane in front of the speaker's body (cf. Winter & Duffy, 2020 Experiment 1 vs. 2), as shown in Figure 2. The gesture was timed such that its stroke was produced simultaneously to a target word – either the verb 'moved' or the adverb 'forward' – or following the target sentence, i.e., 'has been moved (forward) two days **[gesture]**. On what day is it now?' Preparatory and retraction phases were performed as felt natural to the speaker. This entails a retraction movement after the gesture stroke that co-occurred with speech. Winter and Duffy (2020) argue that this could create interference, since it means that the retracting hands are seen as moving backwards into the speaker's lap after having executed a forward movement. To avoid having movements into different directions within the same stimuli, Winter and Duffy (2020) used a post-stroke hold at the end of the forward or backward movement (Experiments 2–4). Our speaker, however, reported that the post-stroke hold felt very unnatural to her. We therefore accepted a retraction movement during the sentence to increase the naturalness of the stimuli.

Across the three experiments, the gesture's direction and position, as well as the position of the sentence accent, were varied. All experiments included the 2-level factor Gesture Direction: forward or backward. In Experiment 1, the question was produced in one of six conditions (= 2 Gesture Direction conditions × 3 Gesture Position conditions), as shown in Figure 3. The factor Gesture Position involved co-timing the gesture with the adverb 'forward', the verb 'moved', or an empty pause following the target sentence before the main question. The verb and post-target conditions did not feature an adverb in the verbal component. This decision was made to assess the direct disambiguating function of the gesture, without any disambiguating cue in speech. However, this meant that Experiment 1 also introduced



Figure 2. Illustration of the gesture used in the stimuli. The example illustrates a forward gesture: (1) preparatory upward movement, (2) stroke phase with a sagittal movement away from the speaker, (3) apex of the gesture, and (4) retraction back to the resting position.

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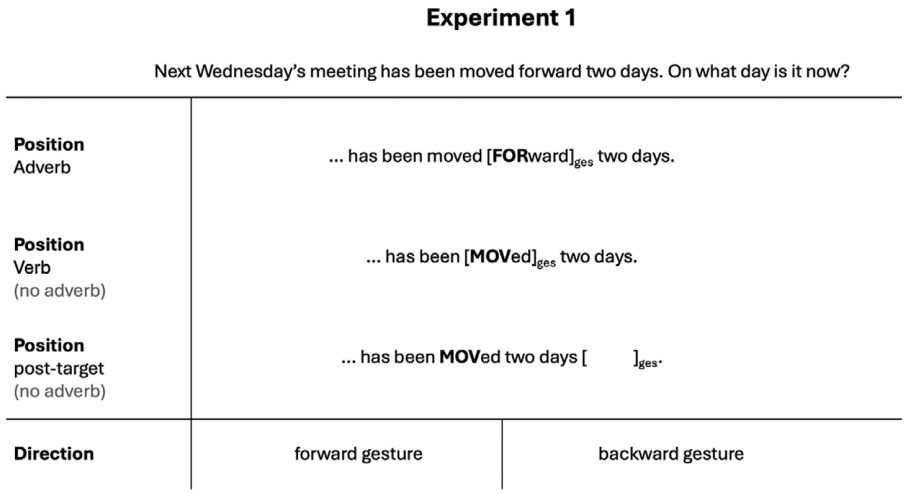


Figure 3. Experimental conditions of Experiment 1. Gesture Direction (forward/backward) is varied across three Gesture Positions (adverb/verb/post-target). Syllables in bold and capitals carry the main pitch accent; [] parentheses indicate the gesture position.

an additional factor, Adverb Presence (adverb/no adverb). To assess the pure influence of Gesture Position, we additionally conducted Experiment 2 (see Figure 4). By and large, this is a replication of Experiment 1, except that the verb and post-target conditions now also featured the adverb 'forward'. In Experiments 1 and 2, the main pitch accent of the sentence was placed on the adverb except for the sentences that did not feature an adverb, in which case it was placed on the verb.

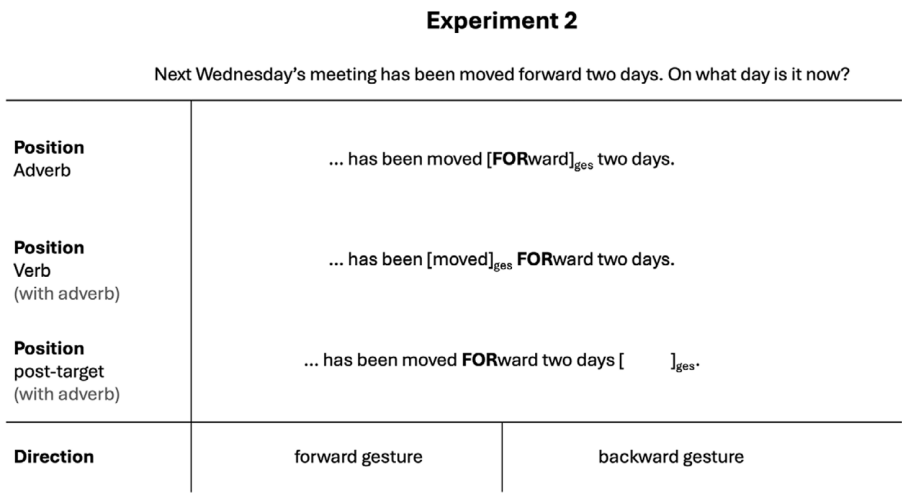


Figure 4. Experimental conditions of Experiment 2. Gesture Direction (forward/backward) is varied across three Gesture Positions (adverb/verb/post-target). Syllables in bold and capitals carry the main pitch accent; [] parentheses indicate the gesture position.

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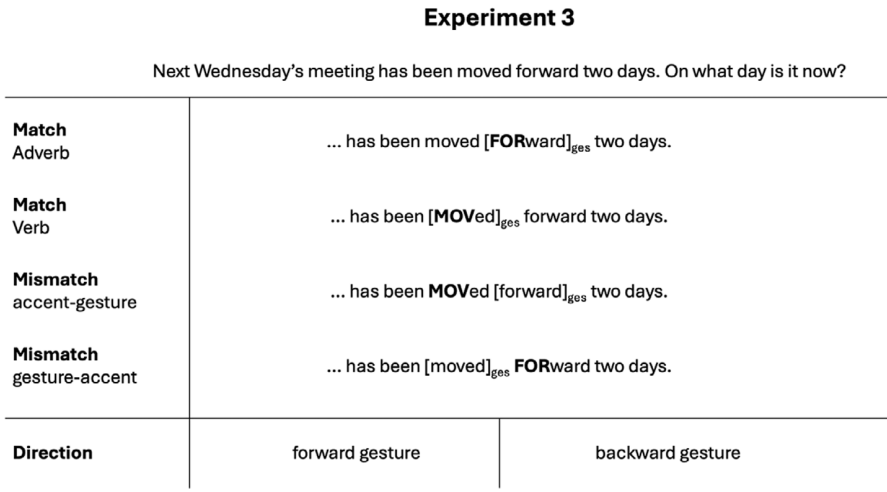


Figure 5. Experimental conditions of Experiment 3. Gesture Direction (forward/backward) is varied across two Gesture Positions (adverb/verb) and two Accent Positions (adverb/verb). Syllables in bold and capitals carry the main pitch accent; [] parentheses indicate the gesture position.

Experiment 3 zoomed in on the role of prosody and applied a $2 \times 2 \times 2$ design with the following factors: Gesture Direction as in Experiments 1 and 2, Gesture Position (adverb/verb) and Accent Position, for which the main pitch accent of the sentence was produced either on the adverb or the verb. The combination of Gesture Position and Accent Position yielded matching and mismatching accent-gesture combinations (see Figure 5). There were two types of matches: either gesture and accent on the adverb, or gesture and accent on the verb. The resulting mismatch conditions had the gesture either precede the accent (gesture-accent) or follow it (accent-gesture).

We recorded the stimuli for all experiments at the Phonology Lab of Goethe University Frankfurt am Main. When asking our speaker to produce stimuli with specific gestures, it is only natural that there are slight variations in the precise timing of speech and gesture with each utterance. We therefore collected multiple different trials within each condition and subsequently annotated the stimuli in ELAN (The Language Archive, 2024; Wittenburg et al., 2006) following the M3D annotation system (Rohrer et al., 2025). This superset of stimuli was pared down by finding the specific videos that were best aligned, i.e., where the gesture was produced as close as possible to the word we aimed to target for a specific condition. This allowed us to maximize experimental control while keeping stimulus production as natural as possible. It also helped to make sure that there were no extraneous cues (e.g., eyebrow or head movements) that were prominent in the videos. Figure 6 illustrates the annotation of one stimulus with a well-positioned gesture. We used Praat (Boersma & Weenink, 2024) for word, syllable, f0-max and f0-min annotations to check accent placement and to pick the most natural but most similar accent contours across conditions. The stimuli we used were produced with L+H* or H* pitch accents within the 'Tone and Break Indices' system for British English accent annotation (ToBI, Silverman et al., 1992).

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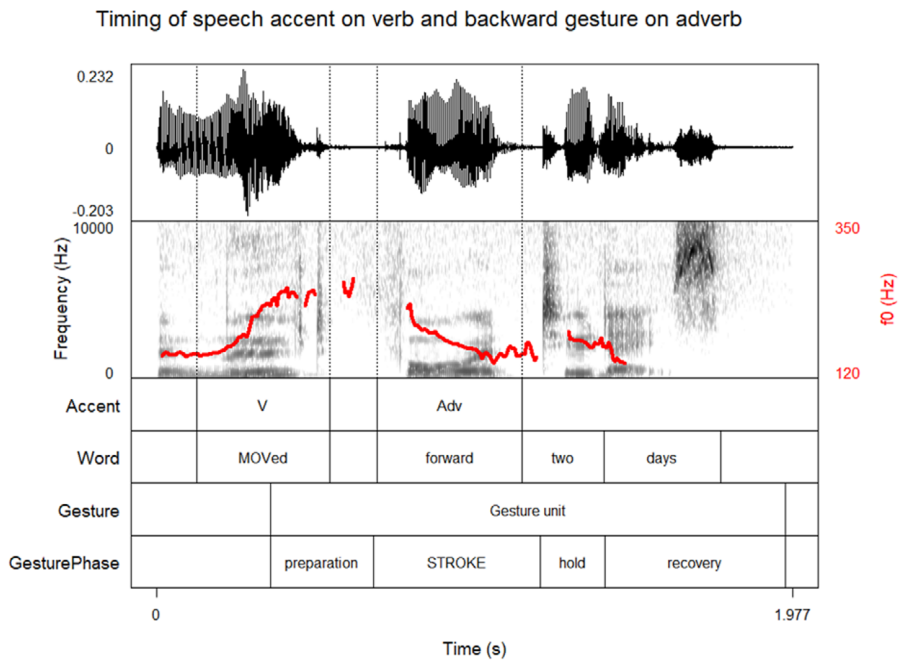


Figure 6. Example of annotations to check the alignment of gestures with the respective constituents for choice of stimuli with PraatPicture (Puggaard-Rode, 2024). A part of the stimulus file is shown here with an L+H* accent on the verb 'moved' (capitalized syllable), while the gesture stroke (capitalized) occurs on the adverb.

4.3. Participants

Participants were recruited via the platform Prolific (Prolific, 2014) and received a reimbursement of 0.60£ (approximately 0,71€) for their participation. We applied the following screening criteria: Participants had to be adults (18+) with no vision or hearing impairment, under the age of 70, they had to be based in the UK or the US, speak English as a first language and have a Prolific approval rate of at least 92%. The experiment was made available only to participants using a computer or tablet (phone participation was not allowed). As all experiments followed a between-participants design, we made sure that participants who took part in one condition could not participate in any other condition across all studies using Prolific exclusion filters. We excluded data points for which the attention question was not answered correctly, or for which responses to the target question were something other than uniquely identifiable 'Monday' or 'Friday' responses, such as 'Tuesday', 'Wednesday', 'Monday or Friday' or 'Just give the new date'.

Three hundred and two participants were recruited for Experiment 1, with 28 participants being excluded (9.3% of total sample, four because of failing to answer the attention question correctly and 24 because of not responding either 'Monday' or 'Friday'). This resulted in a total of 274 valid trials for Experiment 1 (48 forward gesture × adverb, 47 forward gesture × verb, 46 forward gesture × post-speech, 46 backward gesture × adverb, 43 backward gesture × verb, 44 backward gesture × post-speech). The sample consisted of 177 female, 96 male and 1 non-binary participant.

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The median age of the sample was 38 years (mean = 40.4, range = 18–70). Of these, 34 participants indicated that they speak one or more languages in addition to English.

For Experiment 2, 303 participants were recruited and 34 participants were excluded (11.2%, 6 because of the attention question and 28 because of not responding 'Monday' or 'Friday'), yielding 269 valid trials (45 forward gesture × adverb, 40 forward gesture × verb, 46 forward gesture × post-speech, 46 backward gesture × adverb, 45 backward gesture × verb, 47 backward gesture × post-speech). The sample consisted of 112 female and 157 male participants (median age = 43 years, mean = 43.4, range = 18–69). Of these, 47 participants indicated that they speak one or more languages in addition to English.

Four hundred and twenty participants were recruited for Experiment 3, of which 73 were excluded (16.8%, 3 because of the attention question, 70 because of not responding 'Monday' or 'Friday'), yielding 347 valid trials (41 forward gesture × match adverb, 41 forward gesture × match verb, 41 forward gesture × accent-gesture, 45 forward gesture × gesture-accent, 48 backward gesture × match adverb, 40 backward gesture × match verb, 47 backward gesture × accent-gesture, 44 backward gesture × gesture-accent). The sample consisted of 162 female and 185 male participants (median age = 43.5 years, mean = 43.9, range = 19–70). Of these, 50 participants indicated that they speak one or more languages in addition to English.

4.4. Statistical analyses

We conducted all statistical analyses with R version 4.4.2 (R Core Team, 2024). The package *tidyverse* version 2.0.0 (Wickham et al., 2019) was used for data processing; *brms* version 2.22.0 (Bürkner, 2017) was used to fit Bayesian models. Analyses and code are available here: https://osf.io/p8svw/overview

We used Bayesian logistic regression models to analyze the proportion of 'Friday' responses as a function of the following predictors: Experiment 1 included the predictors Gesture Direction (forward/backward) and Gesture Position (gesture on adverb/verb/post-target). In Experiment 2, the predictors were Gesture Direction and Gesture Position (gesture on adverb/verb/post-target). In Experiment 3, the predictors were Gesture Direction, Gesture Position (gesture on adverb/verb) and Accent Position (accent on adverb, verb).[1] Combining the factors Gesture Position and Accent Position allowed us to analyze the matches or mismatches of gesture and prosody. Correspondingly, we ran separate models considering the Match (match, mismatch) and the (Mis)match Position (match adverb, match verb, mismatch acc-ges, mismatch ges-acc) as predictors.

We additionally wanted to see whether we could replicate the likeability effect found in Winter and Duffy (2020), using the simple Likert scale in Experiment 1 and the sum of the Reysen likeability scale (Reysen, 2005) in Experiments 2 and 3. For ease of presentation and consistency with Winter and Duffy (2020), we discuss

[1] As Accent Position by itself, without connection to gesture, is not of central interest for this study (and also did not show any effects), we do not report about this factor in the results section. The interested reader can find plots, models and reports for this factor on OSF: https://osf.io/p8svw/overview. The same applies to the Adverb Presence factor in Experiment 1, which does not deliver any information about this study's central goal.

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proportions of 'Monday'/'Friday' responses in relation to GESTURE DIRECTION with respect to an interaction with LIKEABILITY as a binary factor (median split into a higher and a lower likeability group). Winter and Duffy (2020) did not find likeability effects within each experiment, but only in a conjoined analysis that aggregated results across their Experiments 2–4. We therefore also performed a conjoined analysis where *z*-scored likeability ratings from Experiments 1–3 was split into a higher and a lower likeability group, over which we then ran a model on the interaction between LIKEABILITY and GESTURE DIRECTION. Further, we ran a logistic regression model on the influence of GESTURE POSITION in interaction with GESTURE AWARENESS, based on participants' self-reported information on whether they noticed the gesture in the video or not.

Given that the outcome variable for all main Bayesian logistic regression models was the proportion of 'Friday' responses, positive coefficients for a given condition indicate an increase in 'Friday' responses; negative coefficients indicate an increase in 'Monday' responses. For all models, we used weakly informative priors on the condition effects with a Student's *t*-distribution with $\nu = 5$, $\mu = 0$ and $\sigma = 2.5$. In all experiments, all 2-level factors were deviation-coded (−0.5, +0.5) and 3- and 4-level factors were treatment-coded, with releveled models run to capture all comparisons. We ran models with 8 Markov Chain Monte Carlo (MCMC) chains with 8,000 iterations each (2,000 warmup), which resulted in 48,000 post-warmup samples. Convergence diagnostics indicate that all models were estimated reliably (all $\hat{R}$ values = 1.0; no divergent transitions). We report the probability of a coefficient having the same sign, based on the posterior distribution for that coefficient. Effects were considered robust if the 95% credible intervals (95% CrI) did not include 0. In addition, we used model comparison using Leave-One-Out cross-validation (LOO-CV) to test for interaction effects.

To explore the effect magnitude of the GESTURE DIRECTION factor in each factor level of the remaining factors, we calculated the absolute difference in proportion between the forward gesture and the backward gesture in each other factor level. We then used Cohen's *h* to calculate effect magnitude by running the test over the difference between forward and backward direction proportions. A bigger magnitude thus indicates that the GESTURE DIRECTION effect is stronger at a factor level of one of the other factors, for instance, in a certain GESTURE POSITION.

5. Results

Table 2 shows the proportion of 'Monday' and 'Friday' responses per experiment. Over all experiments combined, 'Monday' and 'Friday' responses were given approximately half and half.

Table 2. Overall proportions of 'Friday' and 'Monday' responses for each experiment

	Data points	'Friday' responses	'Monday' responses
Experiment 1	274	182 (66.4%)	92 (33.6%)
Experiment 2	269	108 (40.1%)	161 (59.9%)
Experiment 3	347	163 (47.0%)	184 (53.0%)
Total	890	453 (50.9%)	437 (49.1%)

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We order our results section as follows. First, we look at the marginal effects of Gesture Direction (Section 5.1) and Gesture Position (Section 5.2), each time ignoring all other effects. Next, we look at gesture-accent matches and mismatches in Experiment 3 (Section 5.3). We then address response differences across conditions in Section 5.4. Finally, we report on Likeability and Gesture Awareness effects in Section 5.5.

5.1. Gesture direction effect

In this section, we look at Gesture Direction without considering any of the other effects. In all experiments, the forward gesture led to more 'Friday' responses, and the backward gesture led to relatively more 'Monday' responses, as shown in Figure 7.

In Experiment 1, 83.0% ($N = 117$) of participants responded 'Friday' after seeing a video with a forward gesture, in contrast to 48.9% ($N = 65$) who responded 'Friday' when seeing a backward gesture. The corresponding Bayesian logistic regression model indicated a strong effect of Gesture Direction (*logit* = +2.19, *SE* = 0.37, *95% CrI*: [1.50, 2.93]), with a high probability of being of the same sign ($p(b > 0) = 1.0$). In Experiment 2, 45.8% ($N = 71$) of participants responded 'Friday' when seeing the forward gesture and 26.8% ($N = 101$) responded 'Friday' when seeing the backward gesture. The corresponding logistic regression model also indicated a strong effect of Gesture Direction (*logit* = +1.18, *SE* = 0.26, *95% CrI:* [0.67, 1.70]), with a high probability of being of the same sign ($p(b > 0) = 1.0$). In Experiment 3, 60.7% of the participants ($N = 102$) responded 'Friday' in the forward gesture condition, compared to only 34.1% ($N = 61$) in the backward gesture condition. As with the other experiments, the corresponding logistic regression model indicated a strong effect of Gesture Direction (*logit* = +1.15, *SE* = 0.23, *95% CrI:* [0.70, 1.59]), with a high probability of being of the same sign ($p(b > 0) = 1.0$).

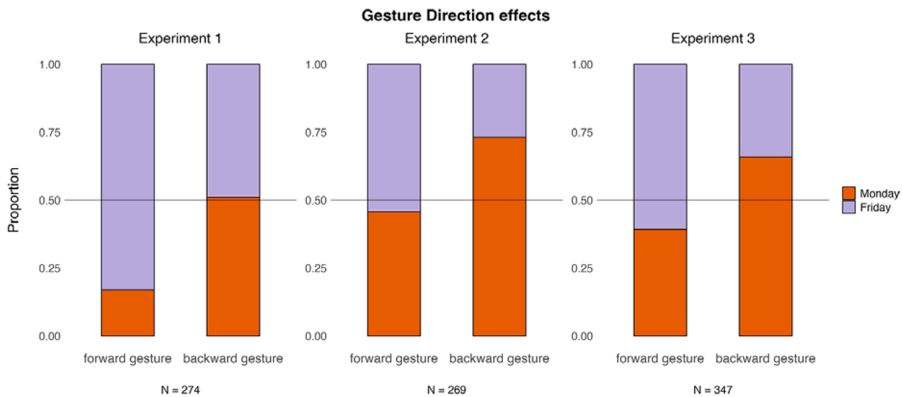


Figure 7. Gesture Direction effects for each experiment; proportions of 'Friday' (purple) and 'Monday' (orange) responses per Gesture Direction (forward/backward); the horizontal line visualizes the 50% mark.

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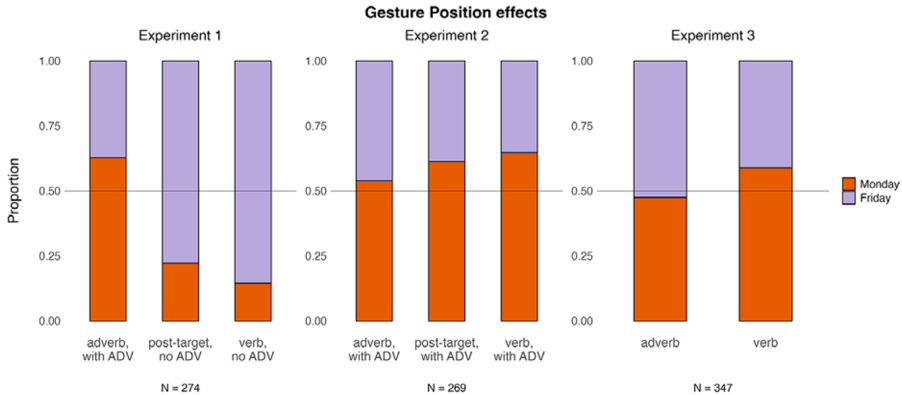


Figure 8. Gesture Position effects for each experiment; proportions of 'Friday' (purple) and 'Monday' (orange) responses per gesture position (adverb/verb/post-target in Experiments 1 and 2). Experiments 1 and 2 contain information about adverb presence; the horizontal line visualizes the 50% mark.

5.2. Gesture position effect

The effects of the Gesture Position factor without considering any of the other factors serve the purpose to assess whether the gesture's placement alone is crucial for its role in shifting the proportion of 'Monday'/'Friday' responses, by addressing whether a certain position evokes stronger or weaker disambiguating effects. Results for Gesture Position are illustrated in Figure 8. In Experiment 1, participants responded 'Friday' much less often with the gesture in adverb position than in the other two conditions. However, recall that in Experiment 1, the verb and post-target conditions did not include an adverb (see Sections 3 and 4.2), and thus the difference between the adverb and the other conditions could be due to the absence of the adverb. For this reason, we do not report inferential statistics for Gesture Position in Experiment 1.[2]

In Experiment 2, when adverb presence was kept consistent, 46.2% of participants (N = 42) responded 'Friday' with the gesture in adverb position, 35.3% (N = 30) responded 'Friday' with the gesture in verb position and 38.7% (N = 36) responded 'Friday' with the gesture in post-target position. The corresponding logistic regression models did not indicate a reliable effect of Gesture Position (post-target–adverb: *logit* = −0.33, *SE* = 0.31, *95% CrI*: [−0.93, 0.27]; post-target–verb: *logit* = +0.13, *SE* = 0.32, *95% CrI:* [−0.50, 0.77]; adverb–verb: *logit* = +0.46, *SE* = 0.32, *95% CrI:* [−0.17, 1.09]).

In Experiment 3, we compared only the adverb and verb positions. 52.5% of participants (N = 93) responded 'Friday' when they saw a gesture in adverb position, compared to 41.2% (N = 70) when they saw a gesture in verb position. The corresponding logistic regression model indicated a relatively weak Gesture Position effect (*logit* = +0.55, *SE* = 0.23, *95% CrI*: [0.10, 1.00]), with a high probability of being of the same sign ($p(b > 0) = 0.99$).

To address interactions with gesture direction, an interaction model in Experiment 2 showed an interaction between Gesture Direction and Gesture Position

[2]The Adverb Presence effect does not allow to examine the effect of Gesture Position properly. Models were run for Gesture Position in the analysis though (indicating an effect between adverb and the other conditions, but not between post-target and verb) and can be found in the RMarkdown.

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in the post-target and adverb condition (*logit* = +1.64, *SE* = 0.61, *95% CrI*: [0.46, 2.87]), with a high probability of being of the same sign ($p(b > 0) = 1$). The model also found an interaction in the post-target and verb condition of which the credible interval barely included zero (*logit* = +1.18, *SE* = 0.63, *95% CrI*: [−0.04, 2.43]), but which had a high posterior probability of being of the same sign ($p(b > 0) = 0.97$). Using LOO-CV, we compared a Gesture Direction × Gesture Position model versus one without interactions. It showed that while the interaction model was slightly more predictive, the difference was small with a high standard error, which indicates that the model without interactions has a similar predictive accuracy to the interaction model (*elpd difference* = −2.1, *SE difference* = 2.8). In Experiment 3, a model without interactions outperforms a Gesture Direction × Gesture Position model in a LOO-CV comparison (*elpd difference* = −0.6, *SE difference* = 0.8), showing that the model without interactions is more predictive.

5.3. (Mis)match of gesture and accent (Experiment 3)

The gesture-accent (mis)matches in Experiment 3 showed that accent position only plays a role in disambiguation in relation to the gesture's position. We combined the Gesture Position and Accent Position factors to assess the effects of a binary Match factor (match: accent and gesture on the same constituent; mismatch: accent and gesture on different constituents) in relation to Gesture Direction, as shown in Figure 9. While the Gesture Direction effect was visible (i.e., more 'Friday' responses with forward gestures, see Section 5.1), no big difference in responses

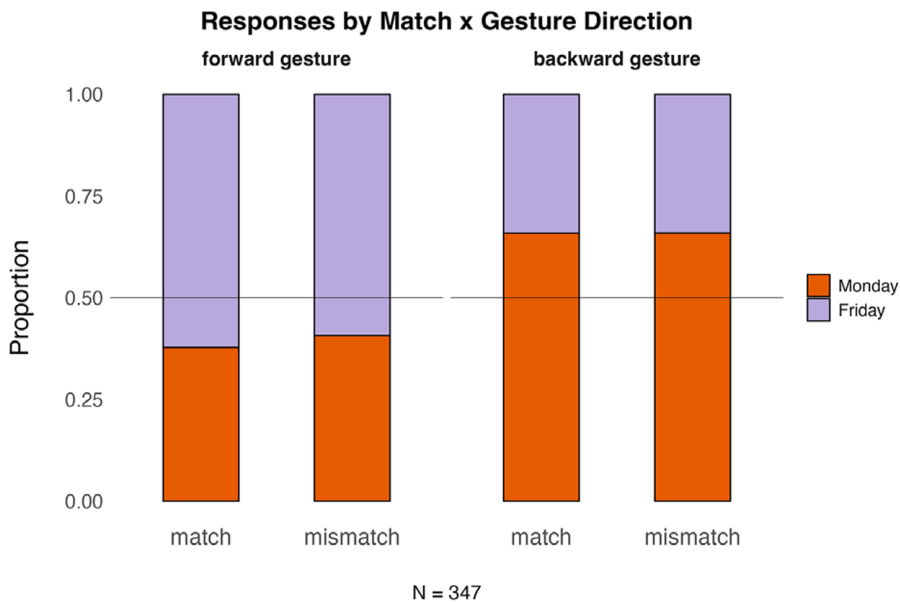


Figure 9. Interaction of Match and Gesture Direction effects in Experiment 3; proportions of 'Friday' (purple) and 'Monday' (orange) responses per match condition (match/mismatch) and gesture direction; the horizontal line visualizes the 50% mark.

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between matches or mismatches was apparent. With the forward gesture, participants responded 'Friday' in 62.2% (N = 51) of the cases when gesture and accent matched, and similarly, they responded 'Friday' in 60.0% (N = 51) of the cases when the two mismatched. With the backward gesture, 34.1% of participants (N = 30) responded with 'Friday' in the match conditions and also 34.1% of participants (N = 31) responded with 'Friday' in the mismatch conditions. Model comparison via LOO-CV showed that a model without the GESTURE DIRECTION × MATCH interaction outperformed a model with interactions (*elpd difference* = −1.0, *SE difference* = 0.3), which is in line with the lack of any noteworthy differences between matching and mismatching conditions reported above. Apart from confirming the GESTURE DIRECTION effect (see Section 5.1 above), the no-interaction model showed that the MATCH factor had no effect on responses (*logit* = +0.06, *SE* = 0.22, *95% CrI*: [−0.37, 0.50]).

To investigate the influence of the timing of the accent relative to the gesture, we then assessed whether results differed as a function of whether the gesture and accent occurred on the verb or on the adverb by addressing the influence of (MIS)MATCH POSITION on responses, as shown in Figure 10. In the matching cases, 49.4% of participants (N = 44) responded 'Friday' when the match occurred on the adverb and 45.7% (N = 37) responded 'Friday' when the match was on the verb. In the mismatching cases, 55.7% of participants (N = 49) responded 'Friday' when the accent preceded the gesture and 37.1% (N = 33) responded 'Friday' when the gesture preceded the accent. The corresponding logistic regression models showed only one reliable effect, namely the difference between accent-gesture and gesture-accent conditions (*logit* = +0.85, SE = 0.32, *95% CrI*: [0.24, 1.48]), with a high probability

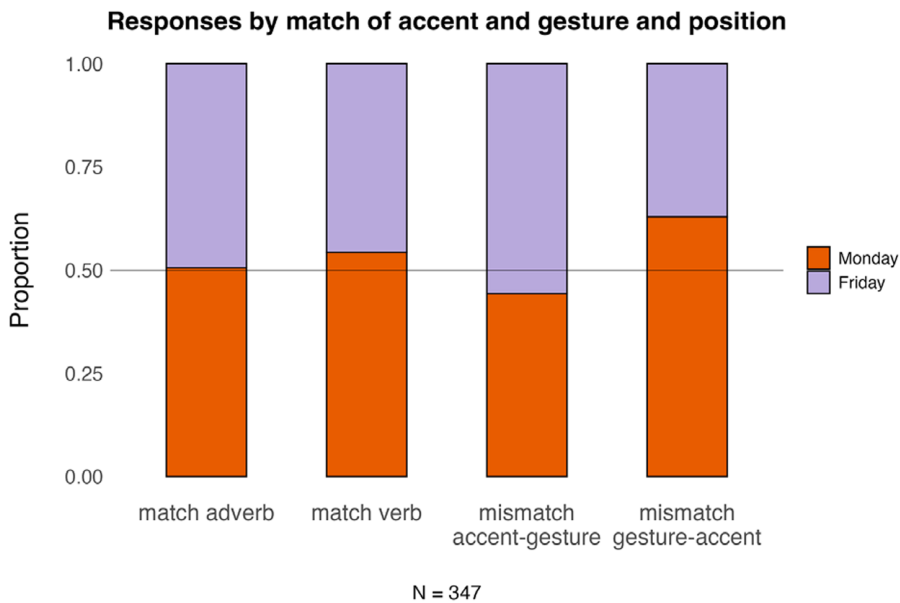


Figure 10. MATCH POSITION effects in Experiment 3; proportions of 'Friday' (purple) and 'Monday' (orange) responses per match position (match adverb/match verb/mismatch accent-gesture/mismatch gesture-accent); the horizontal line visualizes the 50% mark.

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of being of the same sign ($p(b > 0) = 1$). All other levels did not show reliable differences.

5.4. Gesture direction effect magnitude

Table 3 shows Cohen's *h* values for the effect of GESTURE DIRECTION (forward–backward) across all other conditions. The effect is rather large across most conditions, with Experiment 1 having the largest GESTURE DIRECTION effects overall, and Experiment 3 having medium-sized effects. The strongest GESTURE DIRECTION effect was obtained in the post-target position *without* adverb in Experiment 1 (*Cohen's h* = 1.14); the weakest effect was obtained in the post-target position *with* adverb in Experiment 2 (*Cohen's h* = 0.11). Benchmarks for effect magnitude for Cohen's *h* are 0.2 for a weak effect, 0.5 for a medium effect and 0.8 for a strong effect.

Comparing effects within Experiment 1, the results showed that the difference score between gesture directions was higher with the gesture on the adverb than the verb, indicating that when the gesture matched with the adverb influences responses the most (although Cohen's *h* was higher for the verb condition, which is due to the response proportions being close to the end of the proportion scale). The post-target condition showed a large effect of GESTURE DIRECTION with a difference score of 41% and a Cohen's *h* of 1.14. However, due to the experimental setup of Experiment 1, we cannot be sure that this is a pure GESTURE DIRECTION effect, or rather an effect of the absence of the adverb in this condition. Looking at Experiment 2, which included the adverb also in the verb condition, the condition with the gesture on the adverb was stronger (*difference score* = 45%, *Cohen's h* = 0.94) than the gesture on the verb condition (*difference score* = 32.5%, *Cohen's h* = 0.69). When the adverb was present in the post-target condition, the GESTURE DIRECTION effect effectively disappeared (*difference score* = 5.1%, *Cohen's h* = 0.11). Experiment 3 showed the same GESTURE

Table 3. GESTURE DIRECTION difference score (abs(forward-backward)) and effect magnitude of the GESTURE DIRECTION effect based on each other factor (level) for each experiment, using Cohen's *h*

Exp.	Factor	Factor level	Forward gesture Friday (%)	Backward gesture Friday (%)	Difference score (%)	Effect magnitude (Cohen's *h*)
Exp. 1	Gesture position	Adverb	54.2	19.6	34.6	0.74
		Verb	97.9	72.1	25.8	0.82
		Post-target (no adverb)	97.8	56.8	41.0	1.14
Exp. 2	Gesture position	Adverb	68.9	23.9	45.0	0.94
		Verb	52.5	20.0	32.5	0.69
		Post-target (adverb)	41.3	36.2	5.1	0.11
Exp. 3	Gesture position	Adverb	69.5	37.9	31.6	0.65
		Verb	52.3	29.8	22.6	0.46
	Accent position	Adverb	55.8	31.5	24.3	0.5
		Verb	65.9	36.8	29.1	0.59
	Match position	Match adverb	65.9	35.4	30.4	0.62
		Match verb	58.5	32.5	26.0	0.53
		Mismatch accent-gesture	73.2	40.4	32.7	0.68
		Mismatch gesture-accent	46.7	27.3	19.4	0.41

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Position trend as Experiments 1 and 2, in that the gesture on adverb condition elicited a bigger difference between gesture directions (*difference score* = 31.6%, *Cohen's h* = 0.65) than the gesture on verb condition (*difference score* = 22.6%, *Cohen's h* = 0.46).

Regarding prosody-gesture (mis)matches in Experiment 3, only minor magnitude differences emerged between matching conditions (*Cohen's h* = 0.62 for match on adverb and *Cohen's h* = 0.53 for match on verb), but differences were more apparent for the mismatching conditions, where the ordering of gesture and accent modulated the Gesture Direction effect: the gesture effect was stronger when the gesture followed the accent – so when the gesture was placed on the adverb (*difference score* = 32.7%, *Cohen's h* = 0.68) and weaker when it preceded the accent (*difference score* = 19.4%, *Cohen's h* = 0.41).

5.5. Likeability and gesture awareness effects

As discussed in Section 4.4, we performed a median split for ease of presenting percentages in a high and low likeability group. A higher likeability of the speaker increased the proportion of 'Friday' responses with the forward gesture compared to a lower likeability and to the general distribution in Experiments 2 and 3, but not in Experiment 1, as shown in Table 4.

We ran logistic regression models on the interaction of Likeability and Gesture Direction for each Experiment. Experiment 1 did not indicate any interaction between Likeability and Gesture Direction (*logit* = +0.01, *SE* = 0.57, *95% CrI*: [−1.10, 1.13]). Experiment 2 did indicate an interaction between Likeability and Gesture Direction in that the coefficient barely overlapped with zero (*logit* = *+0.90*, *SE* = 0.52, *95% CrI:* [−0.11, 1.93]) and the posterior tests reveal a high probability of being of the same sign ($p(b > 0) = 0.96$). In Experiment 3, we found no interaction between Likeability and Gesture Direction (*logit* = +0.19, *SE* = 0.45, *95% CrI*: [−0.69, 1.07]). *Z*-scoring the scales across all experiments before performing a median split and then running a conjoined likeability model revealed an interaction between Likeability and Gesture Direction (*logit* = −0.48, *SE* = 0.28, *95% CrI*: [−1.03, 0.07]), with a high probability of being of the same sign for the interaction ($p(b < 0) = 0.96$).

Regarding Gesture Awareness, the large majority of participants across all experiments self-reported to have noticed the gesture (*N* = 817; 91.8%). Table 5

Table 4. Proportion of 'Friday' responses per likeability group, experiment and Gesture Direction with difference proportions between directions

Likeability group	Gesture direction	Exp. 1	Exp. 2	Exp. 3
higher likeability	forward	80.0%	64.8%	66.7%
	backward	43.2%	27.0%	37.0%
	difference	36.8%	37.8%	29.7%
lower likeability	forward	84.9%	41.7%	55.6%
	backward	51.7%	26.7%	30.8%
	difference	33.2%	15.0%	24.8%
general	forward	83.0%	54.2%	60.7%
	backward	48.9%	26.8%	34.1%
	difference	34.1%	27.4%	26.6%

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Table 5. Gesture awareness proportions per experiment, gesture position and match position

Condition		Exp. 1		Exp. 2		Exp. 3	
Awareness		Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Gesture position	Adverb	80.9	19.1	95.6	4.4	96.6	3.4
	Verb	84.4	15.6	97.6	2.4	95.3	4.7
	Post-target	85.6	14.4	93.5	6.5	–	–
Match position	Match adverb	–	–	–	–	96.6	3.4
	Match verb	–	–	–	–	92.6	7.4
	Accent-gesture	–	–	–	–	96.6	3.4
	Gesture-accent	–	–	–	–	97.8	2.2

displays the proportions of participant's gesture awareness (yes/no) across different Gesture Positions and Match Positions in all experiments. No consistent patterns are visible in different gesture positions across all experiments; differences between conditions were rather small. Regarding the match position, differences between conditions were also small, except for the match on verb condition having a slightly lower gesture awareness.

We ran logistic regression models to assess the interaction of Gesture Awareness and Gesture Position. In Experiment 1, 229 participants (83.6%) paid attention to the gesture and the model indicated a Gesture Awareness effect (*logit* = −2.40, *SE* = 1.19, *95% CrI:* [−5.12, −0.45]), with a high probability of being of the same sign ($p(b < 0) = 0.99$), showing that participants who did not notice the gesture were more likely to respond with 'Monday'. There was no interaction with Gesture Position. In Experiment 2, 257 participants (95.5%) paid attention to the gesture and the model indicated no Gesture Awareness effect or interactions. In Experiment 3, 331 participants (95.4%) paid attention to the gesture and the model indicated a weak Gesture Awareness effect (*logit* = −1.26, *SE* = *0.66*, *95% CrI*: [−2.63, −0.05]) with a high probability of being of the same sign ($p(b < 0) = 0.98$), showing that participants who did not notice the gesture were more likely to respond with 'Monday'. There was no interaction with Gesture Position, and no interaction with Match Position.

6. General discussion

This study represents both a replication as well as an extension of the gestural effects in the NWQ paradigm. Across three experiments, we replicated the finding that gesture influences how people resolve the ambiguity of the NWQ (Jamalian & Tversky, 2012; Lewis & Stickles, 2017; Tversky & Jamalian, 2021; Winter & Duffy, 2020). At least relatively speaking, we found that forward gestures consistently resulted in more 'Friday' responses than backwards gestures. Given that this study and past studies used slightly different speakers, stimuli, populations and testing contexts, the cumulative evidence for the impact of gesture is now remarkably consistent. Indeed, the NWQ now constitutes one of the clearest demonstrations that co-speech gesture can systematically shape sentence interpretation, and in a manner that is quite substantial, with relatively large effect sizes in terms of raw proportions. At this point, we are no longer asking *whether* gesture matters in this context; we are asking what determines *when* it matters.

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In this study, we explored what aspects of speech, gesture and prosody determine whether a gesture successfully biased interpretation. The key indicator of this was the proportional difference between 'Monday'/'Friday' responses for forward and backward gestures. For this, our most consistent finding was that a gesture had its strongest effect when it coincided with the spatial adverb 'forward'. In contrast, gesture effects were weaker when the same gesture was aligned with the verb 'moved', even though the gesture itself depicted movement. Experiment 3 showed that in the grand scheme of things, manipulating pitch accent placement had relatively little impact when the gesture already coincided with 'forward'. Only when gesture aligned with the verb – the element where gesture also produced weaker effects overall – did prosodic prominence play a marginally bigger role. One interpretation of this finding is that when gesture aligns with the key disambiguating element 'forward' (what we dubbed the *adverb anchoring* account in Section 3), a pitch accent does not confer additional prominence to it; but when gesture is in a position where it has overall weaker effects (on the verb, as suggested by the results from Experiments 1–3), its influence can be boosted by a concomitant pitch accent. Taken together, this pattern of results suggests that semantic anchoring trumps prosodic anchoring, at least in the context of the NWQ.

Since the expectations of the *verb anchoring* and *gesture priming* accounts are co-extensive in the current experimental setup (see Section 3), the results we found also provide little support for a *gesture priming* account. If earlier gestures exerted their influence by biasing the interpretation of subsequent linguistic material, gesture effects should have been strongest when the gesture occurred on the verb, before participants encountered the critical adverb. Instead, we found the opposite.

Likewise, the *gesture salience* account as formulated in Section 3 was not supported by our data. In Experiment 1, when the adverb was absent, forward/backward post-target gestures led to the biggest difference in 'Monday'/'Friday' responses observed across all experimental conditions from all three experiments. Experiment 2, however, revealed that this strong gesture effect entirely depended on the presence of the adverb: when the adverb was restored, forward/backward gestures made minimal difference in a post-target context. The most likely interpretation of this pattern of results is that in Experiment 1, without the adverb, the NWQ is entirely underspecified with respect to directional information, which then allows the gesture to supply the missing directional information. In Experiment 2, however, participants had already encountered the adverb 'forward' and may have settled on an interpretation before the gesture occurred. Participants may be reluctant to revise their initial disambiguation, which means that the gesture is simply not integrated with the NWQ, as suggested by the absence of any meaningful effect on 'Monday'/'Friday' responses in this context.

This parallels the distinction between underspecification and ambiguity. Without the adverb, direction is not under discussion; with the adverb, the direction is linguistically specified, but ambiguous between ego-moving and time-moving perspectives. The difference between the two post-target conditions therefore suggests that results depend on whether gesture contributes missing information (without adverb, strong effect) or speaks to the resolution of an already established ambiguity (with adverb, barely any effect). Clearly, the mere fact that the gesture was temporally isolated did not guarantee a stronger effect on interpretation across the board – only when the directional information was fully unspecified when no adverb was present. It should be noted, however, that gesture awareness was not higher for the post-target

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condition, which may suggest that the manipulation did not achieve its intended effect, i.e., making the gesture more salient.

The presence of adverbs also relates to the fact that we observed overall more 'Friday' responses in Experiment 1 than in Experiment 2. A closer look reveals that this is due to the post-target and verb conditions having more 'Monday' responses when the adverb is present (Experiment 2), compared to when it is absent (Experiment 1). What explains this result? In line with the idea that without the adverb, the question is underspecified with respect to direction rather than ambiguous, listeners may use more of their world knowledge in filling in their understanding of the NWQ. Or, in other words, if the question does not linguistically specify any direction whatsoever, participants likely rely on what they know about meetings in general. Li (2020) showed that in real-world contexts, people experience meetings being more likely moved toward a later date, presumably because moving it toward an earlier date leads to more scheduling complications and may also be dispreferred for social reasons, given that it can cause inconvenience. The gesture itself increases the preference for the 'Friday' response, which is supported by the fact that participants responded 'Friday' more often when they noticed the gesture than those who did not.

Importantly, however, the presence of an adverb had relatively little effect on the main results relating to gestural coordination. Even though the baseline proportion of 'Monday'/'Friday' responses shifted drastically as a function of adverb presence, the difference between forward/backward gestures was 32% in the gesture-on-verb condition with adverb, and 26% in the gesture-on-verb condition without adverb, a mere difference of 6 percentage points.

Taken together, the results suggest that gesture exerts its strongest influence when aligned with the constituent that is most relevant for resolving the ambiguity of the NWQ, which is the word 'forward' in the present paradigm. Moreover, the results from the gesture placement effects in relation to Experiment 3, which also included prosody, suggest that the crucial timing relationship in the NWQ is not gesture-to-accent timing but gesture-to-meaning timing. This indicates that the *prosodic anchoring* account is secondary to an account with semantic restrictions. Our results suggest that gesture matters the most where it is needed the most for disambiguation, even though in natural speech it tends to co-occur with verbs. These results also make a lot of sense in the context of the idea that iconic gestures are difficult to interpret without being further specified by concomitant spoken language (Feyereisen et al., 1988; Hadar & Pinchas-Zamir, 2004; Krauss et al., 1991). A directional gesture needs to occur with 'forward' to be interpretable with respect to ego-moving and time-moving perspectives; since 'moved' itself is relatively unbiased with respect to these perspectives and does not seem to strongly imply a direction (Feist & Duffy, 2015), the gesture has little effect when coinciding with the verb.

Together with Winter and Duffy's (2020) finding that the effect of gesture disappears altogether when no movement is implied, and together with their finding that changing the adverb from 'forward' to 'backward' has a bigger effect than changing gestural direction, these results are in line with the idea that the interpretation of iconic gestures is largely parasitical on speech. Yes, gesture *can* influence whether people think the meeting has been moved to Monday or to Friday, but this effect very much depends on the concomitant language, and how gesture is timed with respect to it.

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In terms of likeability, the individual experiments showed either no or only weak likeability effects. We then ran a conjoined likeability analysis, similar to Winter and Duffy (2020) and replicated an overall likeability effect. This further confirms that likeability affects the perspective that a listener takes upon the speaker's gestures: if the listener has a positive association with the speaker, the listener is more likely to interpret the gesture from the speaker's perspective. However, the results also show that the likeability effects are altogether rather small. Both in the present study and in Winter and Duffy (2020), sufficient power is needed (i.e., aggregating evidence across experiments) for these effects to be discernible.

7. Conclusions

The set of multimodal perception experiments in this article confirms that a gesture's direction influences how people respond to the ambiguous NWQ, i.e, gesture helps in disambiguating between ego-moving and time-moving perspectives (Jamalian & Tversky, 2012; Lewis & Stickles, 2017; Tversky & Jamalian, 2021; Winter & Duffy, 2020). In contrast, responses differed less strongly as a function of *where* within the question the gesture occurred. Across experiments, a clear pattern emerged where gesture produced stronger effects when it was time-aligned with the key disambiguating element (in this case, the adverb). In contrast, prosody played relatively little role. A further finding was that gesture produced a strong effect when it followed a sentence that left the perspective fully unspecified (i.e., no adverb), but this effect dissipated when the sentence included the adverb. These results suggest that even though the direction of a gesture clearly matters in this paradigm, its ability to resolve perspectives clearly depends on concomitant speech. The interpretive impact of a gesture depends on what words it accompanies.

Data availability statement. Preregistrations of the experiments, item videos, data and code for analysis and plotting are uploaded on OSF: https://osf.io/p8svw/overview.

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