Chimpanzees coordinate interrogative markers to ask questions

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Questions serve to initiate and continue conversation as well as to gain information and introduce new topics. In signed languages a question can be signaled by modifying the content of an utterance or by coordinating the use of nonmanual markers (e.g., the questioning look) and manual modulation (e.g., holding the sign for an extended duration). Cross-fostered chimpanzees, who use signs of American Sign Language (ASL), have demonstrated behaviors that appear in human conversation, including question-answer exchanges. The current study describes the production of questions by signing chimpanzees in a conversational context and offers a methodology for quantifying the relationship between nonmanual markers and manual modulation involved in interrogative utterances.

Keywords: chimpanzee, sign language, question, sign modulation, interrogative marking

Introduction

Questions serve to initiate and continue conversation as well as to gain information and introduce new topics (Cifone, 2013; Davis, 1932). The different grammatical structures of interrogatives (questions) and declaratives (statements) signal conversation partners to respond accordingly (Reimchen & Soderstrom, 2017). Cues for differentiating interrogatives and declaratives may be verbal (e.g., use of a WH-word) or nonverbal (e.g., raised eyebrows or intonation). For productive conversation to occur, conversation partners must attend to and use question-related cues. Forms of question-related modulations, of course, vary with the modality of language, i.e., signed or spoken (Zeshan, 2004).

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Cross-fostered chimpanzees, who use signs of American Sign Language (ASL), have demonstrated behaviors that appear in human conversation, including question-answer exchanges, conversation initiation, turn-taking, repairing interruptions, and production of novel information (Bodamer & Gardner, 2002; B.T. Gardner & Gardner, 1975; R.A. Gardner et al., 1992; Hartmann, 2011; Jensvold & Gardner, 2000; Leitten et al., 2012). The current study investigated the production of questions by these chimpanzees.

Producing questions in signed languages

In signed languages a question can be signaled by modifying the content of an utterance, such as including a WH- sign (Branchini et al., 2013; Geraci et al., 2015). Signers can also signal a question by coordinating the use of nonmanual markers and manual modulation (Weast 2008; Wilbur, 2009; Wilbur & Patschke, 1999).

Nonmanual markers

Nonmanual markers occur in a variety of channels such as positioning of the head, body, eyebrow, forehead, nose, mouth, tongue, cheek and eye gaze. These nonmanual markers can further be described as those occurring on the lower face, involving the lips, tongue, and shoulders, which are associated with lexical items; and those occurring on the upper face, involving the eyes, eyebrows, and head, which are associated with syntactic constituents. Nonmanual markers provide morphemic, pragmatic, and syntactic information and are bound by the constituents they modify, as opposed to affective facial expressions that turn on and off gradually (Wilbur, 2000, 2009).

These markers are layered onto utterances (Pfau & Quer, 2010; Wilbur, 2000). The kinesic nature of signed languages allows multiple channels to signal simultaneously. These channels change systematically with different constituents and domains (Weast 2008; Wilbur, 2009; Wilbur & Patschke, 1999). Their uses are systematic and conventionalized. For example, raised eyebrows occur in topicalization, conditionals, and interrogatives. Raised eyebrows are layered with other nonmanuals to mark the topic of an utterance, and multiple instances of raised brow may occur if more than one topic is being discussed. In contrast, raised eyebrows in conditionals can co-occur with raised chin and always occur during the clause that describes the hypothetical situation. Raised eyebrows layered with other nonmanual markers indicate yes-no questions and occur over the entire clause (Pfau & Quer, 2010).

Nonmanual markers in interrogatives

There are two main types of interrogatives, each accompanied by specific nonmanual markers that, when produced simultaneously, are referred to as the questioning look. Yes-no interrogatives are questions that restrict responses to either affirmation or negation. The yes-no questioning look involves raised eyebrows and widening of the eyes with a forward or neutral head position. Conversely, WH- interrogatives are questions that restrict responses to certain functional categories, depending on whether the question included the sign who, what, when, where, why, or how. The WH- questioning look involves a furrowed brow and squinting of the eyes with a forward head position (Baker-Shenk, 1983; Covington, 1973; Dachkovsky et al., 2013; Fischer, 2006; Neidle et al., 2000; Nespor & Sandler, 1999; Valli & Lucas, 1995; Weast 2008; Wilbur & Patschke, 1999). Additionally, Branchini et al. (2013) and Geraci et al. (2015) found that for WH- interrogatives of Italian Sign Language, like many other signed languages, there is a strict word order that is constrained by the presence of the questioning look.

This "questioning look" phenomena occurs not only in ASL but many signed languages across the world. Zeshan (2004) reviewed research on 35 signed languages from around the world and reported that in all 35 languages signers combine the nonmanual markers of eyebrow raise, eyes wide open, eye contact with addressee, head forward position, and forward body posture to signal a question. In this article, we focus specifically on questioning look formation with raised eyebrows.

Manual modulation

Prosody in signed languages consists of the use of nonmanual markers simultaneously layered with manual modulation. Examples of manual modulation include held sign duration, repetition, and speed, all of which are modulated through the timing of the hands (Dachkovsky et al., 2013; Nespor & Sandler, 1999). Like nonmanual markers, the use of manual modulation also is systematic and conventionalized. For example, held sign duration provides many distinct conversational functions depending on its use. A mid-utterance hold may be used to pause for thought or quickly check in with the addressee before the signer continues. An utterance-final hold, however, signals the expectation of a response and therefore transfer of speakership (Cibulka, 2016; Lepeut, 2022).

Manual modulation in interrogatives

For both interrogative and declarative utterances, final signs tend to be significantly longer than signs in non-final positions (Fenlon et al., 2019; Liddell, 1978; Wilbur & Martinez, 2002). However, research suggests that final signs are held

longer than usual in interrogative utterances, specifically until the addressee begins signing their response (Baker-Shenk, 1983; Stokoe et al., 1965; Zeshan, 2004). Holding final signs not only signals the expectation of a response, but ensures the response provided is appropriate to the question (Cibulka, 2016; Groeber & Ponchon-Berger, 2014; Lepeut, 2022).

Signed communication in other apes

The most well-designed and -documented investigation of sign language use in other apes is that of Gardner and Gardner (Gardner et al., 1989; Krause & Beran, 2020; Leavens et al., 2019). The unique cross-fostering environment of these experiments resulted in chimpanzees who can be validly compared with humans (Racine et al., 2008). Ethologists use cross-fostering to study the interaction between environmental and genetic factors by having parents of one species rear the young of a different species (Stamps, 2003). Beginning in 1966, Gardner and Gardner cross-fostered Washoe, Moja, Pili, Tatu, and Dar, raising the infant chimpanzees in a Western middle class home environment (R.A. Gardner & Gardner, 1969, 1975, 1989) using ASL as the means of two-way communication. Their cross-fostering laboratory was designed to mimic the natural language learning and cultural environment of Western human children. Caregivers were a stable team of individuals, some native signers. Each chimpanzee had a core group of caregivers many spending years in the study (R.A. Gardner & Gardner, 1989). In teaching ASL to the chimpanzees, caregivers modeled human parents teaching human children in human homes. For example, they called attention to objects, expanded on fragmentary utterances, and molded hands into the shape of new signs. This environment allowed for a natural method of communication and language acquisition with a constant exposure to conversational use of sign language. Table 1 provides an extensive list of publications detailing the environments, protocols, and variables utilized in the cross-fostering environment and the subsequent institutes where the chimpanzees lived.

The cross-fosterlings acquired and used signs in ways that paralleled human children. The first signs appeared as early as 12 weeks. Their vocabularies grew robustly for the first 60 weeks of cross-fostering (B.T. Gardner & Gardner, 1985, 1994; R.A. Gardner & Gardner, 1969; 1975; 1984) and throughout their lives (Jensvold & Dombrausky, 2019; Metzler, 2011). At the time this study was conducted, vocabulary size ranged from 125 (Dar) to 188 (Washoe) (see Chimpanzee Biographical Information table in appendix). They combined signs into novel,

productive phrases using a variety of phrase patterns and using sign order in consistent, appropriate patterns (B. T. Gardner & Gardner, 1994).

Table 1. References to descriptions of environments, protocols, and records

Elements of research program	Original publication
I. Linguistic and social environment	
Cross-fostering environment of Project Washoe, University of Nevada, Reno	R. A. Gardner, & Gardner (1969, pp. 665–666)
Cross-fostering environment of Replication Project, University of Nevada, Reno	R. A. Gardner, & Gardner (1975)
Institute for Primate Studies, University of Oklahoma	Fouts, & Fouts (1989); Fouts et al. (1982)
Chimpanzee & Human Communication Institute, Central Washington University	Leitten et al., (2012); Jensvold, & Gardner (2000)
II. Protocols	
Teaching protocols	R. A. Gardner, & Gardner (1969, pp. 666–670)
Testing protocols for Project Washoe	B. T. Gardner, & Gardner (1971, pp. 158–161)
Testing protocols for Replication Project	R. A. Gardner, & Gardner (1984)
Criteria for adding a sign to Washoe's vocabulary	R. A. Gardner, & Gardner (1969, p. 670)
Criteria for adding signs to reliable vocabularies in Replication Project	R. A. Gardner, & Gardner (1975)
III. Records relevant to current study	
Video records	Bodamer, & Gardner (2002)
Original transcripts of video records	Shaw (2001)[1]
Transcripts used in current study	Hartmann (2011)
IV. Variables	
Operational definitions of variables used in current study	Hartmann (2011)

Note.
1. Unpublished

As adults at the Institute for Primate Studies (IPS) and the Chimpanzee and Human Communication Institute (CHCI; see Table 1), the chimpanzees continued to sign spontaneously and interactively about activities, meals, games, and events with each other as well as with human familiars (Bodamer & Gardner

2002; D. Fouts 1994; Jensvold & Dombrausky, 2019; Jensvold & Gardner, 2000; Leeds & Jensvold, 2013; Leitten et al., 2012). The chimpanzees had daily access to picture books, toys, clothing, and other objects, many of which were part of their lives in the cross-fostering environment as they are typical parts of the lives of human children. As in the earlier cross-fostering environment, human caregivers continued to ask questions of the chimpanzees and expand on fragmentary utterances. It was during these ongoing casual signed interactions that researchers systematically explored the chimpanzees' conversational behaviors.

The chimpanzees signed spontaneously (B.T. Gardner & Gardner, 1994), initiated conversations (Bodamer & Gardner, 2002), and maintained topics (Chalcraft & Gardner, 2005). When human interlocutors feigned a misunderstanding, the chimpanzees adjusted their responses contingently and appropriately (Jensvold & Gardner, 2000; Leitten et al., 2012). They took turns in conversation (Hartmann, 2011) and shifted gaze patterns as their role switched between signer and listener (Shaw, 2001). The chimpanzees' patterns of conversation with human caregivers resemble patterns of conversation found in similar studies of human children. Table 2 provides a categorized sample of references for relevant findings.

Questions under cross-fostering conditions

Reports of Washoe, Moja, Tatu, and Dar asking questions have appeared in the scientific record since early in the cross-fostering projects. In Daily Field Logs, "…observers recorded spontaneous utterances along with other behavioral developments in a daily journal". (R.A. Gardner & Gardner, 1994, p.206). Observers detailed sign form including any modulations (e.g., size, speed, reiteration, held duration) and social and verbal context (Gardner et al., 1989). Gardner and Gardner reported the cross-fosterlings asking questions and differentiating between declaratives and interrogatives as early as ten months of age (R.A. Gardner & Gardner, 1978, p.54). In an excerpt from the Daily Logs on 12/23/76, KW wrote "Tatu points to flowers [and signs] THERE? with raised eyebrows and prolonged eye contact" (B.T. Gardner & Gardner, 1989, p.238). Similar records continued when the chimpanzees were adults. On 7/26/01, BM wrote "I was almost done serving soup during lunch and was standing in front of Moja to see if anyone wanted any more. Moja looked at me and clearly signed POTATO with a raised brow and held it" (Dombrausky et al., 2018). Gardner and Gardner reported that cross-fostered chimpanzees appropriately responded to questions, utilized various sentence constituents in answering questions, and produced novel information upon request (B.T. Gardner & Gardner, 1975; R.A. Gardner et al., 1992; Rimpau et al., 1989). Table 2 Section II provides a sample of references to these findings.

Table 2. Evidence of linguistic and pragmatic behavior in cross-fostered chimpanzees

Behavior	Original publication
I. Vocabulary and phrase development	
Developing a vocabulary	B.T. Gardner, & Gardner (1985); R.A. Gardner, & Gardner (1969), 1970, 1975, 1984; 1985)
Combining signs into phrases; Using sign order and grammatical structure	R.A. Gardner, & Gardner (1969); B.T. Gardner, & Gardner (1994)
Producing novel multi-sign phrases	R.A. Gardner, & Gardner (1969); B.T. Gardner, & Gardner (1994)
Using different word classes or sentence constituents (e.g., adjective, noun, verb, classifier)	B.T. Gardner, & Gardner (1975, 1994)
Making conceptual errors	R.A. Gardner, & Gardner (1970, 1984)
II. Modulations	
Directional modulations and modulations of place	Rimpau et al. (1989)
Quantitative and qualitative modulations (e.g., size, speed, reiteration, held duration)	Rimpau et al. (1989); Chalcraft, & Gardner (2005); Shiau (2005)[1]; Potosky (2010)[1]
Responding to questions with appropriate sentence constituent	B.T. Gardner, & Gardner (1975); B.T. Gardner et al. (1992)
III. Conversational behavior	
Initiating conversations	Bodamer, & Gardner (2002)
Timing of overlap	Hartmann (2011)
Repairing misunderstandings	Jensvold, & Gardner (2000); Bodamer, & Gardner (2002); Leitten et al. (2012)
Incorporating partner's topic into next turn	Jensvold, & Gardner (2000); Bodamer, & Gardner (2002); Leitten et al. (2012)
Using human gaze patterns	Shaw (2001)[1]
Providing novel information	R.A. Gardner, & Gardner (1984)

Note.
1. Unpublished

Use of questions by signing chimpanzees is also well documented in film. An example of Washoe using interrogative and declarative forms can be readily seen in clips from the film First Signs of Washoe (NOVA, 1974) beginning at minute 44:51. Washoe twice signs TIME EAT? holding the duration of the sign EAT, raising her brows and holding eye contact with her caregiver. After her caregiver

Susan confirms by signing YES, Washoe then declares TIME EAT twice using the same sign content and order, but without raising her brows, nor holding the duration of either sign or eye-contact.

Many years after leaving the cross-fostering laboratory, and after the death of her son, Washoe's first utterance to her caregiver, Roger Fouts, was a question: BABY? (Fouts et al., 1982, pp. 169–170). Subsequent studies utilized video and Daily Logs to track behaviors of the chimpanzees as they grew to adulthood. For example, for 15 days in 1983 at CHCI, experimenters used remotely operated video cameras to record the chimpanzees when human caregivers were absent. These records revealed that these chimpanzees signed amongst themselves (D. Fouts, 1994) and asked one another questions. Of 196 signed utterances observed on tape, 34% were coded as interrogatives (Mendis, 1985). Researchers at CHCI routinely completed Sign Logs describing signs that were established vocabulary items (Jensvold & Dombrausky, 2019; Leeds & Jensvold, 2013) as well as new and unreliable signs, signed interactions between chimpanzees, and novel uses of signs. Leeds and Jensvold (2013) analyzed records covering two years of Sign Logs. Out of 1,057 utterances, 12.5% were coded as requests which included yes-no and WH-questions (p. 229). In a later replication of this Sign Log analysis with records from August 2013 to February 2014, 25% of utterances were coded as requests (Collins & Jensvold, 2020, 2021). Other studies involving these same chimpanzees reported the presence of interrogative markers in both video records (Shiau, 2005; Potosky, 2010) and written records (Dombrausky et al., 2018).

The current study

The current study describes the production of questions by signing chimpanzees in a conversational context and offers a methodology for examining questions in signed conversation. More specifically, we share a methodology for quantifying the relationship between nonmanual markers that make up the questioning look (QL) and manual modulation of holding the sign.

We systematically isolated nonmanual markers (QL) from manual modulation (holding the sign for an extended duration). If the independently coded variables co-occur, then the chimpanzees can be said to utilize the same interrogative markers as human signers. Following ASL, wherein an interrogative is formed by holding the final sign of an utterance and exhibiting QL, we posed four questions with the goal of investigating whether the chimpanzees coordinate the use of these interrogative markers in the same manner as human signers do.

In an utterance made up of only one sign, that single sign is both the initial and final sign. Thus, for single sign utterances we asked:

1. will the duration of single sign utterances be longer when QL is present than when it is absent?

For multi-sign utterances, which have separate initial and final signs, we asked:

2. will the duration of final signs be longer than initial signs regardless of QL?
3. will the duration of final signs be longer than initial signs when QL is present?
4. will the duration of final signs be longer when QL is present than when it is absent?

Method

Participants

Three female chimpanzees, Washoe, Moja and Tatu, and one male, Dar, ranging in age from 16 years to about 26 years at the time of filming, served as participants in the current study (see appendix for Chimpanzee Biographical Information). All spent their early years living under cross-fostering conditions with ASL as means of two-way communication (R.A. Gardner & Gardner, 1969, 1989). From their early years in the cross-fostering laboratory of the University of Nevada, Reno, to the time of filming at the Chimpanzee and Human Communication Institute at Central Washington University, these chimpanzees lived in rich social and linguistic environments regardless of the actual setting. Table 1 Section I provides references directing the reader to detailed descriptions of each of the living environments.

Video corpus

Bodamer and Gardner (2002) video recorded the adult chimpanzees from April 1992 to April 1993 for their investigation of signed interactions. Their efforts resulted in a large, videotaped corpus. Shaw (2001) and Hartmann (2011) developed detailed transcriptions of samples of these recorded interactions. The original video corpus was recorded on Beta tapes. Bodamer then rerecorded the Beta to VHS while adding a time code. We digitized these VHS tapes to .mov format for the current study.

Transcripts

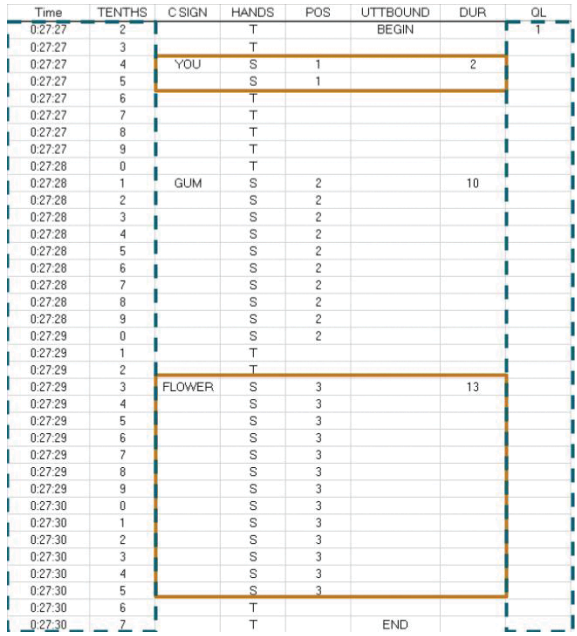
The current study used 160 of the videotaped sessions transcribed by Hartmann (2011). Hartmann's transcripts identified utterance boundaries, beginning times

of each sign, transitions into, between, and out of each sign, and pauses between signs. Each measure was transcribed to 0.1 s; these transcripts did not include modulation. The current study added presence (1) or absence (0) of QL to the transcript for each utterance in which the chimpanzee was actively signing. Table 3 defines foundational terms that are necessary for understanding the transcripts.

Table 3. Operational definitions of utterance components

Sign (S)	A sign began with the 0.1 s identified as the beginning of a sign and continued to the last 0.1 s that a signer's hand was actively producing an ASL sign. Sign modulations, such as reiterations and holds, were considered part of a sign.
Transition (T)	A transition consisted of continuous hand movement between sign and pause or between two signs. More precisely, a transition included movement from pause to sign beginning an utterance, movement from sign to pause ending an utterance and movement from sign to sign within an utterance.
Utterance	An utterance was a stream of one or more signs by one signer connected by transition and bounded by pauses.
Pause	A pause was 0.1 s or more without sign or transition by a signer, i.e. when hands were in rest position.

Figure 1 shows an excerpt of the transcript in which Washoe signs the multi-sign utterance YOU GUM FLOWER. The dashed blue box on the left shows the duration of the entire utterance, beginning at Time 0:27:27.2 and ending at Time 0:27:30.7. YOU, the initial sign, begins at Time 0:27:27.4 and ends at 0:27:27.5, and is bounded by solid yellow lines. The final sign, FLOWER, begins at 0:27:29.3 and ends at 0:27:30.5 and is also bounded by solid yellow lines. The dashed blue box on the right shows that QL was present for at least some part of this utterance. Column HANDS identifies whether the hands were in transition (T) or sign position (S). Column POS indicates the ordinal position of each sign within the utterance, column UTTBOUND indicates the beginning and end of each utterance, and column DUR indicates the duration of each sign. Hartmann (2011) reported that interobserver reliability for all measures ranged from 85 – 100%. Table 4 shows the total number of single sign and multi-sign utterances each chimpanzee produced with and without an accompanying QL.



Time	TENTHS	C SIGN	HANDS	POS	UTTBOUND	DUR	QL
0:27:27	2		T		BEGIN		1
0:27:27	3		T				
0:27:27	4	YOU	S	1		2	
0:27:27	5		S	1			
0:27:27	6		T				
0:27:27	7		T				
0:27:27	8		T				
0:27:27	9		T				
0:27:28	0		T				
0:27:28	1	GUM	S	2		10	
0:27:28	2		S	2			
0:27:28	3		S	2			
0:27:28	4		S	2			
0:27:28	5		S	2			
0:27:28	6		S	2			
0:27:28	7		S	2			
0:27:28	8		S	2			
0:27:28	9		S	2			
0:27:29	0		S	2			
0:27:29	1		T				
0:27:29	2		T				
0:27:29	3	FLOWER	S	3		13	
0:27:29	4		S	3			
0:27:29	5		S	3			
0:27:29	6		S	3			
0:27:29	7		S	3			
0:27:29	8		S	3			
0:27:29	9		S	3			
0:27:30	0		S	3			
0:27:30	1		S	3			
0:27:30	2		S	3			
0:27:30	3		S	3			
0:27:30	4		S	3			
0:27:30	5		S	3			
0:27:30	6		T				
0:27:30	7		T		END		

Figure 1. Excerpt from the transcripts

Table 4. Number of utterances for each chimpanzee

	QL present		QL absent	
Chimpanzee	**Single Sign**	**Multi-sign**	**Single Sign**	**Multi-sign**
Washoe	69	147	61	37
Moja	54	92	47	44
Tatu	54	103	56	50
Dar	62	24	141	72

Variables

Sign position within an utterance

Many authors report the final sign of an utterance is held for a longer duration (Fenlon et al., 2019; Dachkovsky et al., 2013; Wilbur & Martinez, 2002; Lepeut, 2022). To test the replicability of this finding, we compared the duration of final signs of multi-sign utterances to the duration of initial signs of multi-sign utterances. First, we classified each utterance in the transcripts as a single or multi-sign utterance. For multi-sign utterances, there was always one initial sign and one

final sign. However, there could be an infinite number of medial signs. To control for this disproportionate ratio, we included only the initial and final signs in this analysis, depicted by the solid yellow boxes in Figure 1 (i.e., note that the sign GUM, a medial sign, is not outlined in yellow since it was not included in the analysis).

Sign duration

Sign duration was calculated to 0.1 s on the VHS tapes and included only the total time in which the hands remained held in sign position (S), excluding transition (T). We calculated duration using the Excel formula =COUNTA to count the number of cells corresponding to each 0.1 s that the sign was held in place. For example, Figure 1 shows YOU with a duration of .2s and FLOWER with a duration of 1.3s.

Questioning look

The questioning look (QL) consisted of three features: raised brows, widened eyes, and direct eye contact with the addressee. All three features had to be present for QL to be coded as "present". The head also may tilt forward. For each utterance, QL was coded as either present for at least some part of the utterance, or entirely absent.

Coding procedure

The primary researcher watched each utterance from beginning to end and recorded whether QL was present at any time during the utterance. The researcher recorded a (1) indicating that the chimpanzee exhibited QL at any point during the utterance or a (0) indicating that QL was absent during the utterance. This QL code was applied to the entire utterance rather than individual signs. To be blind to the conversational partner's signing while coding QL, the researcher covered both the human conversational partner on the computer screen and the transcripts of the human conversational partner so that only the chimpanzee and chimpanzee's transcripts were visible. The researcher watched, paused, and rewound the videotapes as many times as needed to make a confident determination.

Interobserver reliability

A second researcher, who was familiar with the chimpanzees and ASL, independently coded 20% of the sample, which was randomly selected from the total data set. Following the same coding procedure, the second researcher watched each chimpanzee utterance and recorded the presence or absence of QL. Percent agreement between the two researchers for the presence or absence of QL was 90.42%. Percent agreement has always been used in chimpanzee sign language studies

and others (Bateson & Martin, 2021; Bodamer & Gardner, 2002; R.A. Gardner & Gardner, 1984; Hartmann, 2011; Jensvold & Gardner 2000.

Final sample

Observers were encouraged to code QL when the image was of strong quality and were discouraged from guessing about the presence or absence of QL. A Bad Observation (BO) was recorded if the transcriber was unable to clearly see the chimpanzee's face. Utterances coded as BO were excluded from analyses. Out of Dar's 347 utterances, 48 (14%) were coded as BO. Out of Moja's 330 utterances, 87 (26%) were coded as BO. Out of Tatu's 293 utterances, 30 (10%) were coded as BO. Out of Washoe's 294 utterances, 17 (5%) were coded as BO.

Statistical analysis

We tested the data using the glmmTMB (v1.1.4, Brooks et al., 2017) and multcomp (v1.4–19, Hothorn et al., 2008) packages in the statistical program R (v3.4.2, R Core Team, 2022) for all statistical analyses. For single sign utterances, a generalized linear mixed model (GLMM) compared the presence or absence of QL and chimpanzee identity to the duration of signs.

As in the analysis of single sign utterances, the GLMM for multi-sign utterances compared QL (present vs absent) and chimpanzee identity to the duration of signs. The GLMM for multi-sign utterances also compared the position of the sign within the utterance (initial vs final).

Results

Single sign utterances

Question 1

Table 5 shows that for single sign utterances, sign durations were significantly longer when QL was present than absent (GLMM, $N_{Obs.} = 591$, $N_{Ind.} = 4$; QL (*"absent"*): $b = 0.64$, $z = 7.429$, $p < 0.001$). This pattern appeared in all four chimpanzees.

Table 5. Mean durations (sec) of single signs with or without QL

	Questioning look	
Chimpanzee	**Present**	**Absent**
Washoe	1.2	0.7
Tatu	2.3	0.5
Moja	0.8	0.7
Dar	0.8	0.4

Note.
SE = 0.086 across all chimpanzees

Multiple sign utterances

Question 2

In a comparison of initial and final signs within multi-sign utterances regardless of QL, there was not a significant difference between the mean durations of initial (0.9 s) and final signs (0.8 s) (GLMM, $N_{Obs.} = 942$, $N_{Ind.} = 4$; Position ("*initial*"): $b = -0.061$, $z = -0.913$, $p = 0.361$). There were individual differences among the four chimpanzees, shown in Table 6.

Table 6. Mean durations (sec) of initial and final signs regardless of the QL

	Sign position	
Chimpanzee	**Initial**	**Final**
Washoe	1.0	1.0
Tatu	1.3	0.7
Moja	0.8	0.9
Dar	0.5	0.6

Note.
SE = 0.067 across all chimpanzees

Question 3

There was a significant interaction between QL and sign position ($b = -0.341$, $z = -2.57$, $p = 0.01$). Table 7 shows mean durations of multi-sign utterances with QL present, where durations of final signs were significantly shorter than initial signs ($b = 2.60$, $z = 3.312$, $p = 0.002$).

Table 7. Mean durations (sec) of initial and final signs with QL

	Sign position	
Chimpanzee	**Initial**	**Final**
Washoe	1.1	1.1
Tatu	1.5	0.8
Moja	0.9	0.9
Dar	1.1	0.7

Note.
SE = 0.078 across all chimpanzees

Question 4

In a comparison of only final signs, durations were significantly longer when QL was present vs. absent (GLMM, $N_{Obs.} = 942$, $N_{Ind.} = 4$; QL (*"absent"*): $b = -0.356$, $z = -3.96$ $p < 0.001$). This pattern appears in Table 8.

Table 8. Mean durations (sec) of final signs with or without QL

	Questioning look	
Chimpanzee	**Present**	**Absent**
Washoe	1.1	0.7
Tatu	0.8	0.4
Moja	0.9	0.8
Dar	0.7	0.5

Note.
SE = 0.09 across all chimpanzees

Conclusion

Overall, sign durations were longer when QL was present than absent ($b = 0.733$, $z = 7.404$, $p < 0.001$). This pattern, which was true of single sign and multi-sign utterances, appears in Figure 2. Figure 3 shows this pattern was consistent across all individuals. Table 9 provides a summary of the statistical findings.

Discussion

The current study addressed three major questions. Did these chimpanzees resemble human signers in:

Table 9. Detailed statistical results

Response variable	Factor	Type	N	Estimate	Z	P
Single sign duration ($N_{Obs.}$ = 591)	Questioning look	Fixed	2	0.641	7.429	< 0.001
	Individual	Random	4	*var = 0.08 ± 0.282*		
Multiple sign duration ($N_{Obs.}$ = 942)	Position	Fixed	2	−0.061	−0.913	0.361
	Questioning look	Fixed	2	0.318	7.404	< 0.001
	Position: Questioning look	Interaction	4	−0.148	−2.566	0.01
	initial position: QL absent – present			*−0.621*	*−6.910*	*< 0.001*
	final position: QL absent – present			*−0.356*	*−3.960*	*< 0.001*
	QL absent: initial position – final			*−0.006*	*−0.056*	*0.955*
	QL present: initial position – final			*0.260*	*3.312*	*0.002*
	Individual	Random	4	*var = 0.005 ± 0.072*		

1. holding single sign utterances longer when QL was present than when it was absent?
2. holding final signs longer than initial signs regardless of whether QL was present?
3. holding final signs longer than initial signs when QL was present?
4. holding final signs of their utterances longer when QL was present than when absent?

Regarding the first question, the current study found that Washoe, Tatu, Moja, and Dar coordinated QL with held sign duration in single sign utterances. Likewise, the results of the fourth question show that the chimpanzees held final signs of multi-sign utterances longer when QL was present than absent. This pattern is consistent with how human signers coordinate interrogative markers. (Cibulka, 2016; Dachkovsky et al., 2013; Fenlon et al., 2019; Groeber & Pochon-Berger, 2014; Lepeut, 2022). The chimpanzees' signs indeed tended to be longer when QL was present than when it was absent. Regarding questions two and three however, the chimpanzees did not hold final signs longer in all utterances regardless of QL. In utterances with QL, initial signs were significantly longer than final signs. This pattern in chimpanzees differs from the pattern in humans; human final signs are longer than other signs in an utterance (Cibulka, 2016; Fenlon et al.,

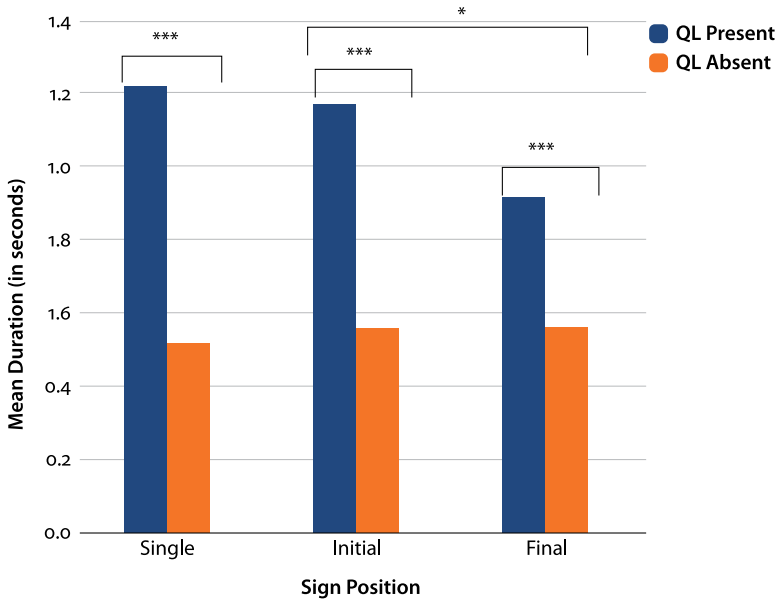


Figure 2. Mean Durations of Sign in Relation to QL
Note. Single Sign $SE = 0.09$; Multi-sign $SE = 0.13$ across all chimpanzees $^{*}p = 0.01$; $^{***}p < 0.001$

2019; Nespor & Sandler, 1999; Wilbur & Martinez, 2002) although Liddell (1978) found topic initial signs were longer in duration than medial signs.

Relationship between the questioning look and duration of signs

The co-occurrence of held sign duration, held eye gaze, and raised brow signals the presence of a question in ASL (Dachkovsky et al., 2013; Wilbur, 2000). Signers of ASL hold final signs of interrogative utterances longer than final signs of other types of utterances, and indeed typically hold the hands in place until recipients begin their response (Baker-Shenk, 1983; Covington, 1973; Lepeut, 2022; Valli & Lucas, 1995). Baker-Shenk wrote:

> These findings conform to the general observation that the final portion of a question is sometimes "stretched out" in time by various means, as noted in Chapter II (7.1). Other evidence of this lengthening tendency across both Yes-No and Wh-questions can be found by comparing the average duration of sentence-final signs in such questions with the average duration of the last sign in rhetorical questions – which for both types of questions in my data, revealed duration at least twice that found in the rhetorical questions. (Baker-Shenk, 1983, p. 172)

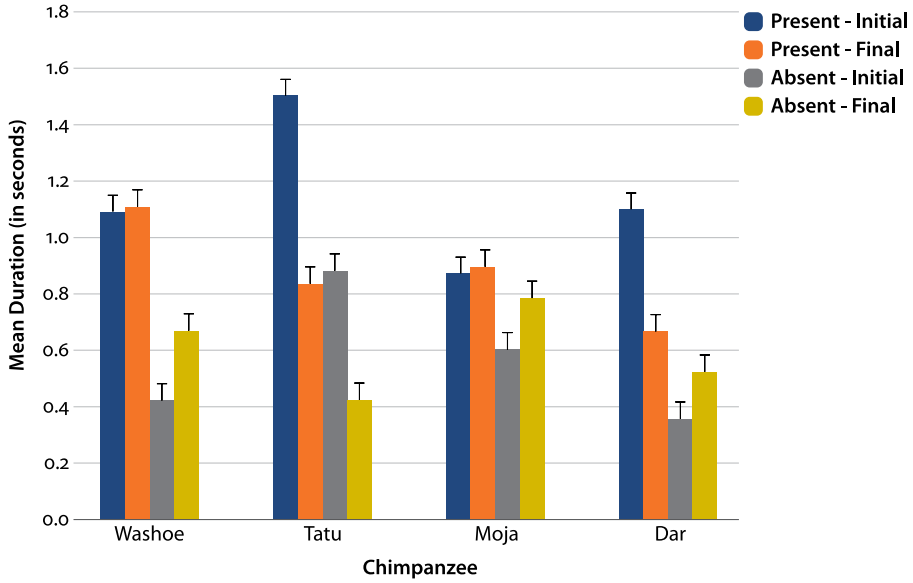


Figure 3. Mean Sign Duration Under Each Condition for All Four Chimpanzee
Note. *SE* = 0.06 across all chimpanzees

Although they differed from humans in their durations of initial and final signs, the chimpanzees in the current study matched the human pattern of coordinating QL with duration of signs. Both chimpanzees and humans held their signs longer when QL was present than when it was absent.

Confirming previous findings

Previous studies involving these same chimpanzees reported interrogative markers in written records (Dombrausky et al., 2018; Leeds & Jensvold, 2013). Observers who were trained in chimpanzee behavior and signs and who had demonstrated reliability in their observations recorded chimpanzee signs and accompanying facial expressions and vocalizations as well other context-related information. In these records, observers used their expertise to judge the presence of QL while the signing took place, a common procedure in research involving children.

In analyses of video records, both Shiau (2005) and Potosky (2010) identified a chimpanzee sign as being held when its duration was longer than 1 s. This definition was based on the use of analogue technology which allowed for reliable analysis only at the macro level of 1 s. Using digital technology, the current study measured the duration of chimpanzee signs to 0.1 s. For single sign utterances, mean duration of signs was 1.1 s with QL and 0.5 s without QL. For multi-sign

utterances, mean duration of initial and final signs was 1.0 s with QL and 0.6 s without QL. The current study provides independent support for the definition of held signs that Shiau (2005) and Potosky (2010) used.

Video analysis in the current study confirms that the chimpanzees used interrogative markers and coordinated their use of these quantitative modulations to ask questions. This pattern appeared in both single and multi-sign utterances and across individuals.

The current study adds to the evidence that these four chimpanzees ask questions. (Shiau, 2005; Potosky, 2010). The finding that an interrogative utterance is formed by combining QL with held sign duration is robust and reliable even when researchers use different operational definitions, procedures, and species of participant. It supports earlier findings that the cross-fostered chimpanzees produced interrogative utterances and employed QL while in conversation (Dombrausky et al., 2018; B.T. Gardner & Gardner, 1989, 1975; B.T. Gardner et al., 1992; R.A. Gardner & Gardner, 1978; Rimpau et al., 1989).

Relationship between the questioning look and sign position

One of the findings from the current study differs from previous findings in human signers. The analysis of duration in the current study showed that two of the four chimpanzees held final signs for a shorter duration than initial signs. Given the previously established similarities between signing of these chimpanzees and signing of humans, this finding was surprising but might be explained by individual differences.

Challenges of establishing reliable measures

Establishing interobserver reliability for the presence or absence of QL was challenging. Initially the goal was to judge, for *every 0.1 s* of an utterance, whether the chimpanzee employed QL. Reliability was 69.90%. The new goal became to judge whether the chimpanzee employed QL for *each sign* in an utterance. Reliability was 74.18%. Only when judging whether the chimpanzee employed QL for *each utterance* did we achieve high reliability (90.42%).

The video corpus used in the current study were digitized VHS tapes that had been dubbed from Beta tapes. With each iteration, quality is lost. Given the technological advancement over the last 30 years since the original data were collected, recent studies of human signers have since been able to isolate many features of ASL prosody to this microscopic degree (Cibulka, 2016; de Vos et al., 2016; Kita et al., 1998; Wilbur, 2000; Wilbur & Martinez, 2002). Future studies

using more current video technology may be better able to isolate each frame of QL. A clearer understanding of boundaries of QL would lead to a better understanding of its relationship with sign duration.

Detailed analyses

Sign languages incorporate multiple channels such as position of head, body, eyebrow, forehead, nose, mouth, tongue, cheeks, and eye gaze. These channels, while independent, are layered and systematically coordinated with syntax (Pfau & Quer, 2010; Wilbur, 2009). They can indicate conditionals, topics, regulators, intonation, and as discussed in this study, questions (Wilbur, 2000, 2009; Wilbur & Martinez, 2002). They are conventionalized within but differ between languages (Branchini et al., 2013; Dachkovsky et al., 2013). We know this through extremely detailed analyses. Researchers code action in channels using FACS (Ekman & Rosenburg, 2005; Weast, 2008) and detailed descriptions. Researchers use digital video that can be analyzed with software, such as ELAN and SignStream, that shows simultaneous coding of channels (Weast, 2008). They use precise timing down to .05s (Cibulka, 2016) operationalizing detail such as velocity, acceleration, and jerk in prosody for example (Wilbur & Martinez, 2002). Kita et al. (1998) segmented signs into phases: preparation, pre-stroke hold, stroke, post-stroke hold, and retraction. De Vos et al. (2016) expanded on these phases to study turn-taking boundaries and sign overlap. These behaviors happen during interactions and researchers also code the coordination of these many behaviors between partners (Groeber & Ponchon-Berger, 2014). Such a dance! These methodologies are a path for future studies of chimpanzee sign language.

Reporting detailed and precise methods is crucial to our understanding of the complexities of signed languages because for results to be truly comparable and conclusions to be accurately drawn, methods must be fully replicable. By reporting all attempts at coding QL, the present study offers transparency into the limitations of the dataset, which could explain discrepancies between our findings and other literature. Despite these limitations, we have provided, to the best of our ability, an adequate description of the phenomena in chimpanzees as it compares to the occurrence in humans.

The chimpanzees were always treated as conversational partners rather than touching computer keys for rewards (Beran & Heimbauer, 2015). As conversational partners, the chimpanzees acquired more than just signs but nonmanual markers as well. These markers function pragmatically to regulate the conversation. Only immersed in conversation could the chimpanzees acquire pragmatic skills such as interrogative markers.

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Appendix and supplemental materials

Chimpanzee Biographical Information

	Washoe, ♀	**Moja, ♀**	**Tatu, ♀**	**Dar, ♂**
Birthdate and birthplace	9/65[a] West Africa	11/18/72 NY, USA	12/30/75 OK, USA	8/2/76 NM, USA
Age in 1993[b]	27	20	17	16
Location and dates of residency				
University of Nevada, Reno	6/66–10/70	11/72–12/79	1/76–5/81	8/76–5/81
University of Oklahoma	10/70–9/80	12/79–9/80		
Central Washington University	9/80–10/07[c]	9/80–6/02[c]	5/81–8/13	5/81–11/12[c]
Fauna Foundation, Quebec			8/13–present	
No. of reliable signs[de]	188	171	157	125
No. of observed signs[df]	57	38	58	50

Note.
a. This is an estimated date since Washoe was wild caught.
b. The age of each chimpanzee at conclusion of data collection.
c. Washoe died in Oct 2007. Moja died in June 2002. Dar died in Nov 2012.
d. According to sign checklists; as of 2005 for Washoe, 2000 for Moja, 2011 for Tatu, and 2010 for Dar.
e. Once the chimpanzee signed a given sign at least once a day over a continual 15-day period, the sign was considered a "reliable sign".
f. If the chimpanzee signed a given sign, but not every day for at least 15 days in a row, then the sign was considered an "observed sign".

Coding manual

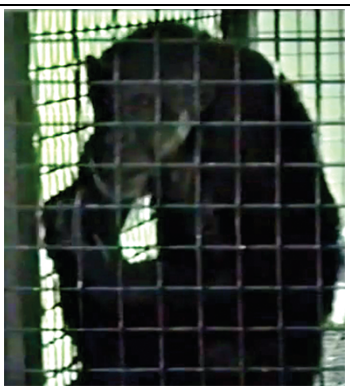
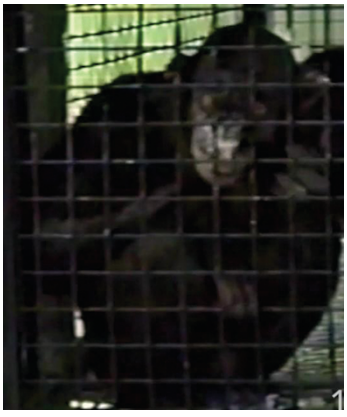
Instructions for coding the questioning look

You will be watching ten video files and coding for the presence or absence of the questioning look. The questioning look is defined as raised eyebrows, widened eyes, and direct eye contact.

1. Once you open the videotape file, cover the top right corner of the screen so that you cannot see the human conversational partner. This is to remain blind to the researcher's signing.
2. Use the "TimeCode" column on the data sheet to identify the times to watch and code the questioning look. You will follow the time shown on the screen, not the time that your computer or media player says. For example, if the utterance occurs from 0:16:34.5 to 0:16:37.7 you will fast forward the tape until the time on the screen reads 0:16:34.5 and watch until the screen reads 0:16:37.7. You may start a few seconds earlier and watch until a few seconds have passed, but do not transcribe outside of the given timeframe. If you believe the questioning look occurs, begins, or continues outside of the given timeframe, indicate this in the "Notes" column of the data sheet.
3. Record whether you see the questioning look as defined above. For each utterance, you will either mark (1) indicating that the questioning look is present, (0) indicating that the questioning look is absent, or B indicating that it is a bad observation. You will mark this in the QL column in the first cell for each utterance.
4. You may watch, rewind, and pause the videotapes as much as needed to get an accurate transcription. The videotapes themselves are rather dark, so you may want to make sure that the room you are watching in is as dark as possible and that the brightness of your screen is on the highest setting. You will complete this process for each utterance in the entire data sheet.

Examples of QL for Each Chimpanzee

Chimpanzee	**QL present**	**QL absent**
Washoe		

Chimpanzee	QL present	QL absent
Moja		
Tatu		
Dar		

Examples of chimpanzee utterances

Example 1. *Dar, utterance #149*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:15:28	3		T		BEGIN		0
1:15:28	4		T				
1:15:28	5		T				
1:15:28	6	HURRY-THAT	S	1		1	
1:15:28	7		T				
1:15:28	8	GIMME (index)	S	2		7	
1:15:28	9		S	2			
1:15:29	0		S	2			
1:15:29	1		S	2			
1:15:29	2		S	2			
1:15:29	3		S	2			
1:15:29	4		S	2			
1:15:29	5		T				
1:15:29	6		T				
1:15:29	7		T				
1:15:29	8		T		END		

Example 2. *Dar, utterance 152*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:19:16	5		T		BEGIN		0
1:19:16	6	DAR (no contact!!)	S	1		2	
1:19:16	7		S	1			
1:19:16	8		T				
1:19:16	9		T				
1:19:17	0	TICKLE	S	2		1	
1:19:17	1		T				
1:19:17	2	CHASE	S	3		3	
1:19:17	3		S	3			
1:19:17	4		S	3			
1:19:17	5		T		END		

Example 3. *Dar, utterance 226*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
0:09:04	5		T		BEGIN		1
0:09:04	6		T				
0:09:04	7		T				
0:09:04	8		T				
0:09:04	9	GUM	S	1		24	
0:09:05	0		S	1			
0:09:05	1		S	1			
0:09:05	2		S	1			
0:09:05	3		S	1			
0:09:05	4		S	1			
0:09:05	5		S	1			
0:09:05	6		S	1			
0:09:05	7		S	1			
0:09:05	8		S	1			
0:09:05	9		S	1			
0:09:06	0		S	1			
0:09:06	1		S	1			
0:09:06	2		S	1			
0:09:06	3		S	1			
0:09:06	4		S	1			
0:09:06	5		S	1			
0:09:06	6		S	1			
0:09:06	7		S	1			
0:09:06	8		S	1			
0:09:06	9		S	1			
0:09:07	0		S	1			
0:09:07	1		S	1			
0:09:07	2		S	1			
0:09:07	3		T				
0:09:07	4		T				
0:09:07	5		T				
0:09:07	6		T		END		

Example 4. *Tatu, utterance 13*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:48:41	4		T		BEGIN		0
1:48:41	5		T				
1:48:41	6		T				
1:48:41	7		T				
1:48:41	8	CHEESE	S	1		1	
1:48:42	9		T				
1:48:42	0	HURRY-GO	S	2		1	
1:48:42	1		T				
1:48:42	2		T		END		

Example 5. *Tatu, utterance 2*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:47:23	9		T		BEGIN		1
1:47:24	0		T				
1:47:24	1	EAT	S	1		22	
1:47:24	2		S	1			
1:47:24	3		S	1			
1:47:24	4		S	1			
1:47:24	5		S	1			
1:47:24	6		S	1			
1:47:24	7		S	1			
1:47:24	8		S	1			
1:47:24	9		S	1			
1:47:25	0		S	1			
1:47:25	1		S	1			
1:47:25	2		S	1			
1:47:25	3		S	1			
1:47:25	4		S	1			
1:47:25	5		S	1			
1:47:25	6		S	1			
1:47:25	7		S	1			
1:47:25	8		S	1			
1:47:25	9		S	1			
1:47:26	0		S	1			

Example 5. *(continued)*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:47:26	1		S	1			
1:47:26	2		S	1			
1:47:26	3		T				
1:47:26	4		T				
1:47:26	5	TIME	S	2		19	
1:47:26	6		S	2			
1:47:26	7		S	2			
1:47:26	8		S	2			
1:47:26	9		S	2			
1:47:27	0		S	2			
1:47:27	1		S	2			
1:47:27	2		S	2			
1:47:27	3		S	2			
1:47:27	4		S	2			
1:47:27	5		S	2			
1:47:27	6		S	2			
1:47:27	7		S	2			
1:47:27	8		S	2			
1:47:27	9		S	2			
1:47:28	0		S	2			
1:47:28	1		S	2			
1:47:28	2		S	2			
1:47:28	3		S	2			
1:47:28	4		T				
1:47:28	5		T				
1:47:28	6		T				
1:47:28	7		T				
1:47:28	8	EAT	S	3		18	
1:47:28	9		S	3			
1:47:29	0		S	3			
1:47:29	1		S	3			
1:47:29	2		S	3			
1:47:29	3		S	3			
1:47:29	4		S	3			

Example 5. *(continued)*

TIME	TENTHS	CSIGN	HANDS	POS	UTTBOUND	DUR	QL
1:47:29	5		S	3			
1:47:29	6		S	3			
1:47:29	7		S	3			
1:47:29	8		S	3			
1:47:29	9		S	3			
1:47:30	0		S	3			
1:47:30	1		S	3			
1:47:30	2		S	3			
1:47:30	3		S	3			
1:47:30	4		S	3			
1:47:30	5		S	3			
1:47:30	6		T				
1:47:30	7		T				
1:47:30	8		T				
1:47:30	9		T				
1:47:31	0	TATU	S	4		6	
1:47:31	1		S	4			
1:47:31	2		S	4			
1:47:31	3		S	4			
1:47:31	4		S	4			
1:47:31	5		S	4			
1:47:31	6		T				
1:47:31	7		T		END		

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