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MODELS OF THE SPEAKER'S TEMPORAL ORIENTATION IN VIRTUAL REALITY AND THEIR IMPACT ON HUMAN-MACHINE INTERFACE SYSTEMS

Abstract: *The manuscript addresses models concerning the speaker's temporal orientation during communication within virtual reality (VR). VR denotes an environment constructed through computer technologies and technical apparatus. Presently, VR is regarded as an experimental domain or research methodology.*

The research was procured via experiment and analyzed 725 reactions from 24 participants, identifying temporal deictics that indicate temporal proximity or distance, which helped delineate temporal orientation modalities within VR.

This research seeks to delve into the complexities of temporal orientation models within VR environments, concentrating on their role in shaping communication and optimizing human-machine interaction (HMI). Through a detailed VR-based experimental framework, the study investigates cognitive and communicative processes, uncovering distinctive temporal orientation models and their variations, which are influenced by extralinguistic factors. The analysis further highlights the speaker's temporal orientation in VR, referred to as virtual-temporal deixis*, which forms a*

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unique communicative-indicative coordinate system. The results underscore VR's utility as a powerful tool for exploring cognitive and communicative dynamics, alongside mechanisms of language transformation. Moreover, the findings offer a theoretical basis for developing HMI systems that more closely align with human temporal perception, fostering more intuitive and natural user interactions.

Keywords: *virtual-temporal deixis, deictics, models, VR, speaker behavior, orientation, HMI.*

1. Introduction

The growing use of virtual reality (VR) in recent years has created new challenges for understanding the perception of time and its cognitive transmission in the digital space. The article explores the concept of the speaker's temporal orientation within the framework of VR. VR is an emerging field that is important for understanding cognitive and communicative dynamics in immersive environments. Its innovation is based on a thorough experimental study of temporal deixis in VR, which allows us to get an idea of this special environment in which traditional time landmarks are changing and rethinking.

By VR, we mean a digital environment designed to simulate interactive three-dimensional spaces that reproduce both real and imaginary scenarios. This technology allows users to experience various degrees of immersion – from partial to full immersion in a VR environment (Lanier, 1992; Castronovo et al., 2013). By creating stimuli that accurately mimic sensory signals coming from a person, VR systems are able to elicit responses corresponding to cognitive, more precisely motor actions and reactions in real time. This ensures a dynamic and responsive interaction between the user and the environment (Lanier, 1992; Powell, 1996). In addition, objects in VR are perceived as having a spatial presence, creating the illusion of physicality and enhancing the sense of realism in virtual space (Bryson, 2013). VR environments can be described as the artificial reproduction of real or imaginary worlds that may or may not obey physical laws (Fox et al., 2009). This combination of sensory alignment and spatial perception makes VR a powerful tool for both practical and experimental applications in various fields.

It is worth noting that these qualities of VR stem from the very properties of the art environment. VR embodies five key properties known as the "Five Selves": visibility, immersion, interactivity, intuitiveness and intensity, proposed by McMillan (1994) and Sherman & Judkins (1992). These properties form the fundamental basis for VR technology. Interactivity is often emphasized as one of the key characteristics VR, distinguishing it from other digital environments. Equally important are the concepts of presence and immersion. Presence refers to a psychological state in which users feel physically located in a virtual world, while immersion includes both technology that creates an adaptive, attractive environment and psychological absorption that disconnects users from their real environment, allowing them to perceive virtual space as reality. The effectiveness of VR depends on the dynamic interaction between interactivity, presence and immersion (Steuer, 1992; Walsh & Pawlowski, 2002; Ryan, 2015; Mütterlein, 2018; Slater & Wilbur, 1997; Witmer & Singer, 1998). Nosov (2000) also highlights interactivity, generality, relevance and autonomy as the main properties that are influenced by the user's perception of time. Relevance is determined by what is happening here and now, while autonomy refers to the subjective perception of space and time in VR. Interactivity measures the extent to which users can change the VR environment in real time (Gryaznova, 2013; Macmillan, 1994).

The properties of VR reflect the virtual space-time continuum, as reality itself is inconceivable without time and space. Each point in space is defined by three coordinates, and time is determined by the point of reference on the time axis (Blascovich et al., 2002). However, the perception of VR is not merely a matter of spatial or temporal measurement; it is closely tied to the cognitive mechanisms through which individuals construct experiences of stability and safety. As Muhic (2024) argues, conceptual metaphors of space such as walls, barriers, and protective boundaries serve as cognitive frames that ensure a sense of security and continuity. These domains of protection and limitation are not only spatial but also temporal, helping users establish reference points when traditional temporal markers are disrupted in immersive environments.

In this context, the notion of a reference point becomes crucial for understanding temporal orientation in VR. A reference point functions similarly to the deictic center in language, providing a temporal anchor that allows the organization of events relative to the present moment. Temporal deixis is expressed through temporal adverbs and the grammatical category of time, which defines time intervals relative to the act of speaking (Erzinkyan, 1978; Zherebilo, 2010). In most languages, time is perceived linearly, representing a unidirectional axis along which events of the past, present and future are sequentially arranged (Benveniste, 1956). The deictic center, usually corresponding to the moment of speech, serves as a reference point for the organization of these temporal connections, and grammatical tenses – past, present and future – are tied to this center. The present tense corresponds to the moment of speech (now), the past tense refers to the time before the speech act (to the present), and the future indicates the time following the speech act (after the present) (Apothéloz, 2021; Bondarko, 2001; Jespersen, 1924; Marino, 2020). This structure provides clarity in the sequence and interpretation of events in the communication process.

Various concepts for allocating reference points consider positioning along the time axis relative to communicative moments. Reichenbach's model (1947: p. 289) outlines three points: the moment of speech, the moment of the event, and the point of reference. Apresyan's concept (1986: p. 21) incorporates these and adds a fourth component –the speaker's time, distinct from the moment of speech. This theory connects the "point of reference" and "moment of speech," defining relative time versus absolute time, with the point of reference aligning with the moment of speech (Apothéloz, 2021; Baranzini & de Saussure, 2021; Bondarko, 1990; Haspelmath, 1997: p. 23; Smith, 2006: p. 92).

In our study, we are trying to identify, systematize all temporal relationships/structures and present them in the form of behavioral models. Our research is based on an experiment conducted in a VR environment. The purpose of the experiment is to study the speaker's deictic behavior in VR. Analyzing the reactions in various simulated scenes, we are trying to solve several problems: to determine the speaker's coordinate system and build models of the speaker's communicative behavior in VR in order to understand the temporal orientation in VR; demonstration of the effectiveness of VR as a tool for the study of cognitive and communicative processes; development of a unique communicative orientation coordinate system specific to VR.

This work uses a multimodal approach to the study of linguistic data on cognitive processes in VR, with an emphasis on the perception of time as the fourth dimension of reality. The cognitive processes of speakers in a virtual environment remain insufficiently studied, especially with regard to the features of communication and deictic behavior, including the temporal orientation of participants. Analyzing the temporal deixis, the authors of the study determine the methods of temporal orientation characteristic of various scenes and communicative behavior. Here, "deictic" includes lexical (pronouns, adverbs, interjections), morphological (some lexemes, affixes, postfixes) and syntactic means (syntagmas, sentences) with indicative semantics.

To deepen our understanding of these issues, modern linguistics requires the introduction of innovative interdisciplinary research methods, as well as flexible and effective technologies to study various processes such as analysis and learning. One of these technologies is VR, which currently, in addition to the rest, is actively functioning as an experimental platform and research methodology. The versatility of VR makes it possible to explore complex cognitive and communicative phenomena, which makes it a valuable tool in advancing linguistic research. Its widespread use demonstrates the integration of various modalities such as speech, gestures, gaze and facial expression, as well as the manipulation of virtual space and objects in it. This highlights the numerous advantages of VR, which makes it possible to explore complex cognitive processes (Peters, 2019: p.899; Zinchenko et al., 2015: p.61).

Although the research is primarily based in linguistics and cognitive science, particularly in the study of temporal deixis – how time is referenced in communication – it also has indirect implications for other scientific fields, such as human-machine interfaces (HMI).

VR has the ability to simulate both real and fantasy environments, allowing participants to actively interact in these immersive environments. By eliminating the artificial spatial boundaries that usually exist between stimuli and participants, VR promotes more natural and direct interaction in the simulated space. Hence, this approach allows to assess the degree of immersion of the user in a highly realistic three-dimensional environment (3D), where the quality of the data collected is much higher compared to traditional experimental methods using two-dimensional computer monitors (Fox et al., 2009; Peeters, 2019). The enhanced sense of presence and realism provided by VR enhance the user's depth of perception, offering a more accurate understanding of human behavior. In addition, this technology reflects key aspects of human-machine interaction (HMI), which makes it an invaluable tool for studying cognitive and communication processes in artificial environments (Partarakis & Zabulis, 2024).

The data provided and the theoretical basis for improving interfaces and systems that respond better to user actions, create more natural and intuitive interaction conditions. In our opinion, this knowledge can help in the development of HMI systems that provide a better user experience by more accurately matching how people perceive time and interact with it in artificial conditions. This may be due to the provision of data and a theoretical basis for improving interfaces and systems that respond better to user actions, resulting in more natural and intuitive interaction conditions. Thus, the knowledge gained can help in the development of HMI systems that provide a better user experience by more accurately matching how people perceive and interact with time in artificial environments, in particular in VR (De Crescenzio & Frau, 2013; Katona, 2021; Shi et al., 2020). In this article, we will also try to present some considerations and recommendations for solving a number of HMI problems.

2. Design and Methodology

In this section, we present the stimulus material and describe the scenes and scenarios created in the VR environment. We outline the experimental conditions and detail the methodological approach used in the analysis, including data collection and processing. Additionally, we explain the principles guiding the experiment and the framework used to interpret the cognitive and communicative behaviors observed in the VR setting.

The experiment is carried out in a VR environment and it involved 24 Russian-speaking participants (12 men and 12 women), all residents of the city of Perm with higher or incomplete higher education and limited experience with VR devices. A fragment of the virtual environment is shown in Figure 1.

Figure 1. A fragment of VR environment (Sc3)

The VR environment was created using Unreal Engine 4.22, featuring a rectangular-shaped bar environment with 11 tables (4 round, 7 square) and 2 bar counters (one L-shaped, one shorter). The referent, represented by a bottle, was placed on three different tables during the experiment, sequentially labeled R1, R2, and R3 (see Figure 2).

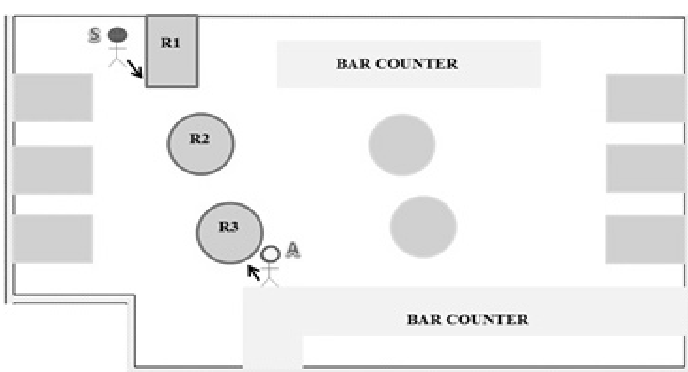

Figure 2. Virtual room plan with its components (Sc1)

The experiment consisted of five scenes: three person-oriented and two distance-oriented. Person-oriented parameters focus on the spatial and communicative relationship between the speaker and addressee, emphasizing face-to-face or close-proximity interactions, often within the same field of view and using personal deixis. In contrast, distance-oriented parameters involve interactions where the speaker and addressee are farther apart or in different fields of view, requiring indirect communication strategies and reliance on spatial deixis to reference objects or locations outside the immediate interaction space (Fillmore, 1982; Anderson & Keenan, 1985; Jungbluth, 2003; Diessel, 1999).

Each scene in our experiment involved different combinations of three parameters: the relative positioning of the speaker and addressee (face-to-face, face-to-back, side-to-side), the positioning of the referent within the internal or external communication space, and whether the referent was within or outside the field of view of the communicants. These variations created unique communicative situations for each scene:

1. **Sc1**: A person-oriented, face-to-face interaction where the referent is located within the internal communicative space, visible to both the speaker and the addressee.
2. **Sc2**: A person-oriented, face-to-face interaction with the referent positioned in the external communicative space, visible to the addressee but located behind the speaker.
3. **Sc3**: A person-oriented, face-to-face interaction where the referent is in the external communicative space, visible to the speaker but situated behind the addressee.
4. Sc4: Distance-oriented with the speaker standing alongside or behind the addressee, and the referent in the external communicative space within the field of vision of both.
5. Sc5: Distance-oriented with the speaker to the right of the addressee and the referent in the external communicative space within the speaker's field of vision but outside the addressee's view.

Participants completed a questionnaire and were briefed on the task: to request the addressee (an animated character) to retrieve the referent from the table. The experimenter altered scenes, requiring the speaker to locate the referent and instruct the addressee accordingly. The communication process was recorded using an internal camera in the VR glasses and an external camera, with the videos synchronized and merged for analysis (see Figure 3). A total of 725 reactions were recorded, each combining linguistic deictics and, if present, gestures and other modalities:

1) *Возьмите бутылку, стоящую на втором от вас столе, справа. Даже прямо. (делает шаг вперед)*[2]

Figure 3. A fragment of the synchronized recording of both cameras

The experimental data undergoes a multi-step processing and classification procedure. Verbal reactions are decoded and synchronized with body movements, with cues segmented into phrases and gestures. This synchronization is essential as gestures act as deictic elements for some participants. The annotated material is then processed in IS 'Semograph' (Belousov et al., 2017), creating a project for each subject's reaction, including context and metadata such as gender and education. This stage provides data on component connections and their metadata links. Each reaction is analyzed for deictic or communicative semantics, categorizing syntagmas into deictic and communicative classes. The result is a universal classifier with categories like 'Structure of the Situation', 'Type of Communication', and 'Means of Communication', visualized as an interactive circular graph in the SciVi analytics system (Ryabinin et al., 2020). The interactive graph of deictic and communication parameters can be viewed at: https://scivi.semograph.com/?preset=Graf_obschee_gender.json[3]

The full design of the experiment is presented in Taleski's work (2024).

[2] The speaker's movements are described in parentheses.

[3] When you click on the links, the data flow window loads; to view interactive graphs, click on the VISUALIZE link located in the upper-right corner of the window.

3. Results and discussion

Through the analysis of the collected data, several distinct models of the speaker's temporal orientation in VR have been identified. Participants primarily employ linguistic elements such as verb tenses, temporal expressions, and adverbs to navigate and express time within the VR environment. These linguistic markers serve as key tools for anchoring communication in time. This paper focuses specifically on the variability in the use of temporal adverbs, highlighting their role in shaping temporal orientation during interactions in VR. The following sections will outline the specific models of temporal orientation derived from these observations, detailing their characteristics and applications within the VR context.

Table 1: *Factors and Their Influence on Temporal Adverb Frequency in VR Interactions*

Factors	Scenes					**Type of the scene**		**Gender**	
	Sc1	Sc2	Sc3	Sc4	Sc5	Person oriented	Distance oriented	Male	Female
Variability share	0.111	0.090	0.097	0.090	0.175	0.100	0.132	0.091	0.021

From Table 1, it is evident that the usage of temporary adverbs varies based on gender and scene types. In the first four scenes, a consistent usage of temporary adverbs is observed, ranging from 0.090 to 0.111. However, in scene 5, the proportion of occurrence is nearly double (0.175).

The large number of temporary adverbs (deictics) used in the speech of participants in Sc5 compared to other scenes can be explained by several factors. The scene might possess heightened emotional intensity due to the fatigue of the participants, as it is the last in the sequence, which leads to more expressive and time-anchored speech, where speakers use more deictic means to emphasize the immediacy or urgency of their statements. Additionally, if Scene 5 focuses on temporal events or the sequence of actions, such as recounting a timeline, references to past moments (events), or, less frequently, planning for the future, this could naturally lead to a more frequent use of temporal adverbs to clarify the sequence and timing of events. Thus, Sc5 can be defined as a communicative situation with more complex temporal references, requiring participants to frequently anchor their statements in time, which may be related to shifts in narrative time, discussions of past events, or detailed sequencing of actions.

Regarding scene types, there is a higher proportion of temporary adverb occurrence in Distance-oriented scenes (0.132) compared to Person-oriented scenes (0.100). In terms of gender, male participants exhibit a proportion of temporary adverb occurrence more than four times higher (0.091) than that of female participants (0.021). This significant disparity may suggest that men in this study tend to anchor their speech more frequently in time, possibly reflecting differences in communication styles between genders. Results also has shown that men and women may prioritize different aspects of communication, with men potentially focusing more on the temporal structure of events, which could explain the higher use of temporary adverbs among male participants.

In discussing models of temporal orientation in VR, it is noteworthy that speakers primarily orient themselves in time by utilizing present tense verb forms, as exemplified in e.g.1, largely due to the experimental task itself. Here, the speaker serves as the point of reference, aligning with the actual time of speaking in the VR environment (Figure 4).

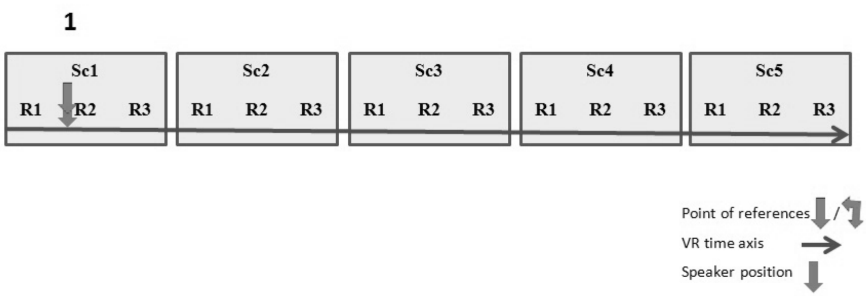

Figure 4.Visual representation of Model 1

This model of the speaker's orientation is also observed when the speaker uses temporary adverbs indicating the actual moment of speaking. Firstly, we are referring to temporal adverbs such as *теперь* "now", *сейчас* "at this moment", and *пора* "it's time", which are used by speakers to anchor their statements in the present moment, guiding the listener's understanding of when an action is expected to occur or is being referenced, as seen in the example:

2) *Ближайший справа от вас стол* теперь *содержит бутылку, пожалуйста, передайте её мне. (Опускает голову вниз, смотрит влево, шевелит пальцами).*

In this model, communication is specifically oriented toward the VR addressee, with all three key elements of the communicative interaction – the speaker, the addressee, and the referent – fully embedded within the VR environment. This alignment effectively constructs a temporal axis unique to the virtual setting, enabling temporal relationships to be established and navigated within the VR space. Such a configuration allows for precise temporal coordination and interaction, where the dynamics of time are integrated directly into the virtual context, reflecting the fluidity of temporal deixis in artificial environments. This can be qualified as Model 2. Unlike Model 1, which is used for real-time tasks and provides responsiveness and clarity, Model 2 can be applied to scenarios that reflect a more subtle and flexible interaction between communicants. Thus, by integrating both models, HMI systems can provide a more natural and intuitive interface, reflecting the complexity of human perception of time and increasing user engagement in the VR environment.

The presence of a separate time axis in VR, alongside the real-time axis, becomes more apparent in reactions devoid of spatial reference points:

3) a) *(Поворачивается на 90 градусов. Кашель.) Я надеюсь вам не составит труда (складывает руки на животе) даме принести ту бутылку, (проводит правой рукой, горизонтально указывая) которая стоит за вашей спиной.*

b) Ещё ближе *за вашей спиной. (кивает)*

c) Совсем близко *(мотает головой),* только руку протянуть. *Прошу вас. (пригласительно проводит правой рукой, горизонтально указывая)*

In example 3, the speaker's three consecutive reactions (a, b, c) form a cohesive and integrated discourse. The speaker uses coordinating words to reference previous situations, drawing on earlier contexts to address the task at hand. These lexical cues help connect past interactions with the current communicative act, ensuring continuity and aiding the addressee (the VR character) in completing the task successfully.

This type of temporal orientation remains confined to a single scene, in this case, Sc3. The speaker's use of what can be termed "chain orientation" is restricted to the boundaries of that specific scene, without extending beyond it. This suggests that the speaker perceives the scene as a distinct unit or episode, with a clear start and end, anchored along a specific temporal axis that parallels the VR time continuum.

Chain orientation, as observed here, represents a unique model of temporal alignment within VR. It is characterized by sequential references within a single interaction, where temporal coordination is established and maintained only within the given scene, as illustrated in Figure 5.

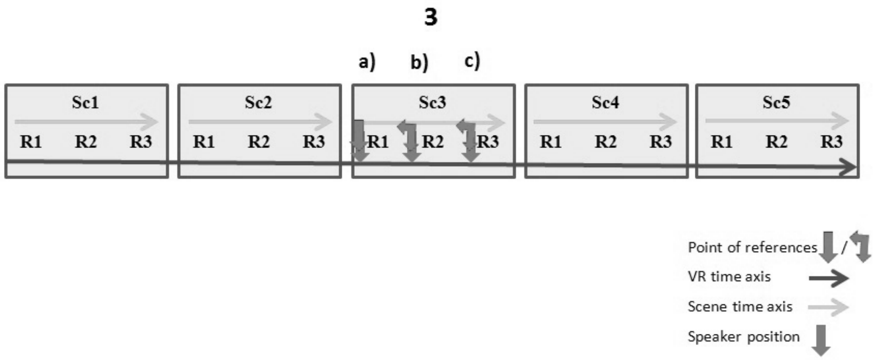

Figure 5. Visual representation of Model 3

Model 3 indicates the ability of users not only to make references to several time points of reference in VR, but also to simultaneously perceive several time frames, interacting with the environment in the present, observing events in the past or manipulating them without changing contexts. The time dimensions in this model can be dynamically and smoothly integrated and synchronized, which creates a sense of a sequence of actions in one "virtual" time axis, creating a dynamic, interconnected time experience that is convenient for a successful HMI.

It is important for HMI within the framework of Model 3 to be able to work with multiple time contexts simultaneously, offering a customizable time interface that improves understanding of complex systems and allows you to create potential linear, multi-level narratives in VR.

It is noteworthy that in e.g. 3, the primary spatial point of reference is the body of the addressee. During orientation, the speaker utilizes a specific spatial reference point from a previous interaction, known as chronotope orientation, to contextualize and indicate elements of the current situation. This strategy enables the speaker to draw on past spatial-temporal relationships to guide communication in the present context.

A clear example of this is demonstrated in example 4, where reference points combine elements from both the current and prior situations. In this case, the addressee becomes the focal point for establishing temporal deixis, serving as the anchor for orienting the speaker's temporal and spatial references within the communicative act (see Figure 6). This method highlights the integration of past and present reference frames, facilitating continuity and clarity in VR-based interactions.

4) *Молодой человек,* до вас *девушка не могла забрать, возьмите бутылку, пожалуйста, слева от меня бутылка стоит...*

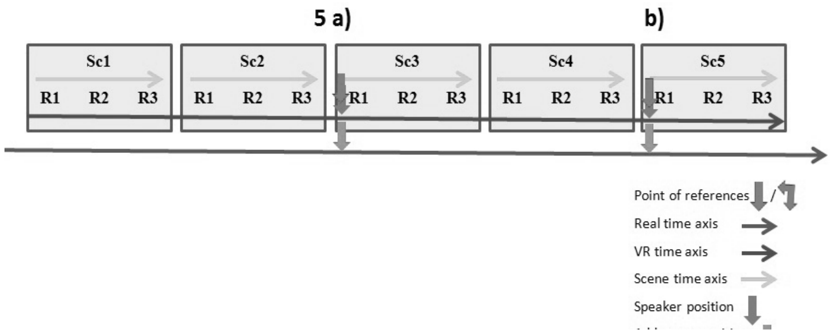

Figure 6.Visual representation of Model 4

Model 4 can be thought of as a model where the boundaries between time, space, and user perception are blurred. In this model, the virtual environment and the speaker's perception of time and space are deeply interconnected and adapt in real time.

This model allows speakers to perceive time and space in a multidimensional form, interacting with several versions of the script at the same time. The speaker, within the framework of orientation, can move through the "layered" environment of events, rearranging the perception of time and space in such a way as to better match his immediate needs and goals, encouraging the speaker to think outside the framework of linear temporal progress, and creating a personalized chronotope structure. Thus, Model 4 involves the creation of interactive and adaptive interfaces for the design of HMI systems that will contribute to the chronotope.

In Model 4, we can note the frequent use of verbs, adverbs, and expressions such as *теперь* (as in e.g. 2), *сейчас*, *снова*, *опять повернулись*, etc., to reference previous situations. In this context, the previous situation serves as a direct or indirect reference point.

The previous situation serves as an effective reference point only when it is directly relevant to the current task and sufficient for its successful completion. This is evident in example 2, where the speaker explicitly highlights the earlier absence of an object on the table. By contrasting this with the current state – where the table, now functioning as the spatial reference point, contains the referent – the speaker effectively utilizes past context to frame the present scenario. This approach underscores the importance of temporal and spatial continuity in virtual environments, as the reference point not only aids in orientation but also reinforces the logical progression necessary for task completion.

It is crucial to note that both participants of the communicative act should be aware of the earlier situation. Otherwise, the orientation to the previous situation remains incomplete, as one of the communicants lacks information about the state of the VR objects until the time of the speech act. In cases where the previous situation is referenced to highlight a specific aspect of the communicative act, thereby adding context or enhancing its meaning – such as in the phrase *опять повернулись* "you turned again" – the prior situation serves to support effective communication in the present context. However, when the previous situation is used in this way, it is classified as an indirect reference, as it enriches the current interaction without being directly necessary for task completion.

When using these time deictics, different types of orientation models are detected.

5) a) *(оборачивается вправо-влево) Где теперь? (поднимает руки раскрытыми ладонями вниз) Позади вас через два стола находится стол, на котором на краю находится бутылка. Можете передать мне ее? (шевелит пальцами рук)*

b) *Я её* сейчас *сама возьму (улыбается). Возьмите, пожалуйста, ту бутылку (махнула правой рукой влево).*

In Model 5, we discuss orientation in the present tense. The speaker is oriented relative to themselves and their body at the moment of the speech act. In e.g. 5a), they pose a question, attempting to clarify the spatial coordinates of the referent's location. These are reactions specific to situations at the beginning of a particular scene. The speaker often requires a certain amount of time to orient themselves after scene changes, searching for the addressee and determining the coordinates of the referent in VR, as their location changes instantly after the previous scene concludes.

In example 5a, the challenge revolves around determining the direction of communication. If the question is directed inward, from the speaker to themselves (autocommunication), where the sender and receiver are the same, we can assert that the speaker functions as the primary reference point. In this case, the speaker is oriented with respect to the actual speech act along the VR time axis, positioning themselves relative to their own actions in the virtual environment.

Alternatively, the communication could initiate external interaction, where the speaker's actions or requests necessitate input or feedback from outside the VR environment. This occurs when the speaker seeks to clarify the location of an object or adjust their behavior based on self-observation, addressing an addressee who exists outside the virtual realm, typically an experimenter. The external addressee operates on a real-time axis distinct from the VR temporal framework. In such a scenario, it becomes evident that the speaker, while immersed in VR and aligned with its time axis, is also able to perceive and interact with the real-time axis. This dual awareness highlights the complexity of communication in VR, as the speaker navigates both virtual and real-time temporal planes simultaneously.

Here we are talking about synchronizing orientation in virtual time with the expectation of feedback in real time, when the speaker is oriented both along the time axis of VR (for internal actions) and along the axis of real time (for external interactions). With such interaction, the HMI system is required to effectively integrate these measurements. This synchronization leads to the alignment of various time dimensions (axes), in particular, to temporal convergence. Thus, Model 5 emphasizes the ability of users to manipulate multiple events on different time axes, and the point of intersection of these dimensions can be defined as a point of temporal convergence. This model is clearly shown in Figure 7.

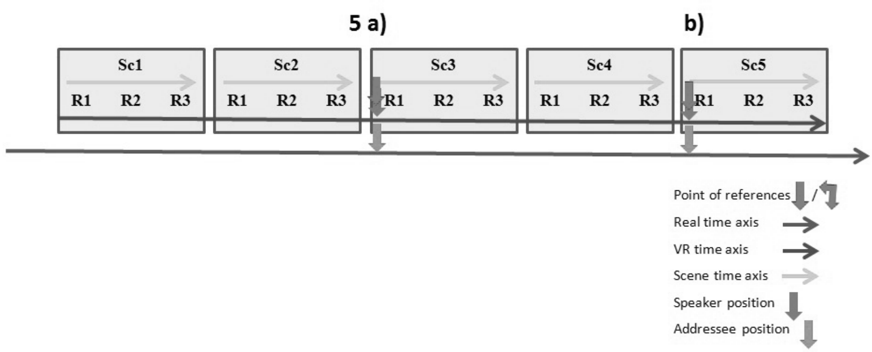

Figure 7.Visual representation of Model 5

In certain reactions, such as in e.g. 6, participants refer to a specific scene that has already been completed when they complete a task.

6) *Бутылка осталась там, где стояла* два стола назад. *Будьте добры, заберите её, пожалуйста.*

Here we observe a model centered on the presence of shared memories among communicants (Figure 8). In this model, the reference point encompasses both a specific scene from the past (temporal orientation) and a particular VR object – the table (spatial geocentric orientation).

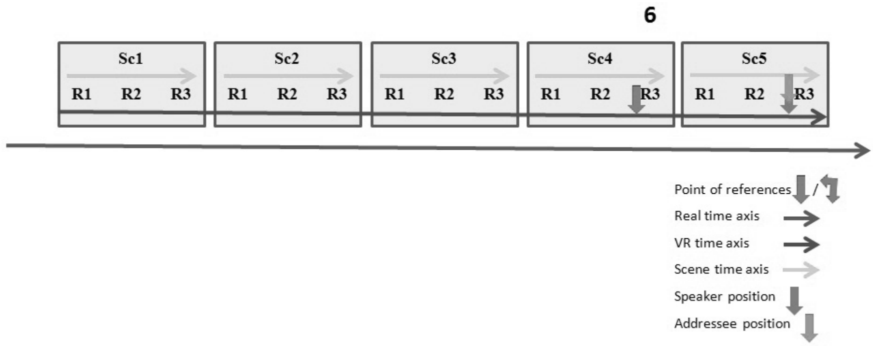

Figure 8.Visual representation of Model 6

Another model of temporal orientation merits attention, as it shares similarities with the previous behavioral strategy, yet exhibits some notable differences. Unlike models 1-6, which mainly focused on linear time structures, Model 7 may represent a significant deviation because it takes into account nonlinear or distorted time structures. In this model, the speaker directs their attention to a previously completed scene prior to initiating a new task, without explicitly referencing the earlier context by name:

7) *Мы повторяемся...*

In this scenario (Figure 8), there is no explicit reference to a specific scene, which suggests the existence of multiple timelines. The speaker employs phrases such as "repeat," "again," or "the same thing," which, on one hand, suggest that a similar action was previously performed in an identical context. On the other hand, ambiguity arises, as it remains unclear which past situation the speaker is referencing, leaving the time reference uncertain. This lack of clarity disrupts the chronological order, with temporal markers becoming less precise. The ambiguity can apply to both the events unfolding within the VR environment and the actions performed by the experimenter. A similar instance is observed in the expression *Опять тоже самое* ("Again, the same thing"), where the speaker hints at repetition without providing a clear temporal reference, further complicating the temporal framework. This highlights the challenge of maintaining consistent time markers in virtual communication.

The speaker's deployment of temporal strategies by using temporal deictics to navigate parallel temporal realities is a critical component in developing innovative communication methods for effective engagement with complex temporal frameworks. Consequently, Model 7 can be characterized as a scenario in which the speaker simultaneously engages with multiple timelines, allowing for interaction with temporal markers associated with different points in time concurrently.

This indicates that the speaker perceives the scenes as time cycles in which the user repeatedly goes through the same time interval. In such cases, the speaker perceives recurring events as being in a time loop, where he constantly returns to the same moment. This can strongly influence communicative behavior, in particular the speaker's use of a unique temporal deixis to perform a successful communicative act. It directly testifies to the consequences in the interaction of human and machine.

It is noteworthy that in e.g. 7, uncertainty also arises concerning the inclusivity of the personal pronoun "We". Consequently, from the context, it remains ambiguous who, besides the speaker, the pronoun "We" encompasses: the addressee, the experimenter, or both.

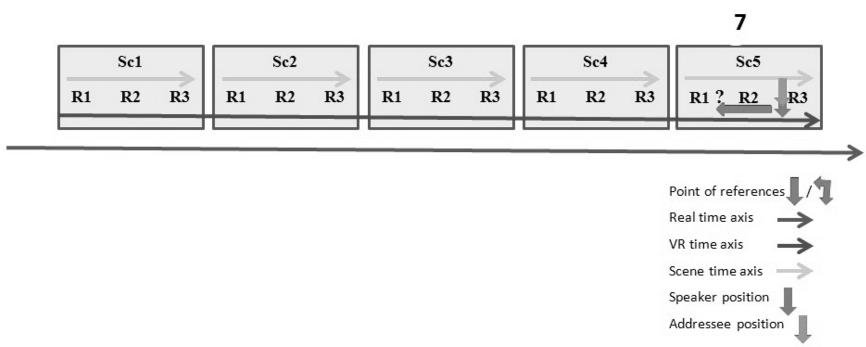

Figure 9.Visual representation of Model 7

It is noteworthy that participants frequently exceeded the designated task parameters, resulting in the utilization of various temporal expressions, including forms of the past and future tense, along with adverbs with temporal semantics.

Regarding the future tense, it is important to highlight that it is only present in reactions when the speaker deviates from the task and envisions various events intended to occur in the future, as exemplified in e.g. 8. The reference point in such instances is the speaker themselves and the current time of speaking within the VR environment.

8) *Слушай, к нам сегодня* придут, *наверно, все столики* будут *заняты (делает жест левой рукой, поднимает ее к очкам, делает указательный жест указательным пальцем правой руки). Поставь на каждый столик по такой бутылке,* будет свадьба, *в общем, каждому столу по закуске и такой бутылке, что рядом с тобой.*

Participants occasionally articulate adverbs or complex expressions denoting specific time periods, such as *сегодня*, or particular times of the day. The designation of specific times of the day is primarily observed when participants use greetings, such as *добрый день*, *доброе утро* etc. This phenomenon primarily occurs when the speaker exceeds the predefined task boundaries of the experiment.

In addition to verbal means, a model of temporal orientation in VR was also identified through the use of non-verbal cues. Specifically, the thumbs-up gesture (Figure 10) was observed. Following each statement, the participant turns to the experimenter and performs a thumbs-up gesture. This gesture in this context can be interpreted in two ways: first, as an endorsement of an action (initiating a certain process), and secondly, as an indication of the successful completion of a communication act (concluding the successful fulfillment of a particular task). Both interpretations entail temporal semantics.

Given that the speaker immediately redirects their attention to the experimenter after engaging with the VR character, this model can be understood as signifying a shift in the direction of communication – transitioning from the virtual environment to the external world via non-verbal cues. This redirection highlights the dual-layered nature of interaction, where participants oscillate between immersive virtual tasks and real-world communication. The frequent occurrence of such shifts may suggest a lower level of immersion in the VR environment, as participants continually break the virtual context to engage with external elements. This behavior potentially reflects limitations in the VR system's ability to fully captivate the user's focus, or it may indicate the participants' cognitive struggle to remain immersed within the virtual setting.

Figure 10. A fragment of nonverbal communication with the addressee outside of VR

These observations suggest that VR functions not only as a medium for modeling temporal deixis but also as a mechanism for restructuring the user's communicative and cognitive experience. By creating conditions in which participants simultaneously navigate multiple temporal axes, VR fundamentally alters the perception of temporal relations. This transformation is particularly relevant for educational and training contexts, where immersive environments can strengthen memory consolidation, improve task sequencing, and foster new forms of temporal awareness that are unattainable in traditional learning settings. Consequently, VR introduces a qualitatively new communicative reality in which temporal deixis becomes both a tool for interaction and a medium for cognitive development.

4. Conclusion

The conducted study yields several key conclusions concerning both the predefined objectives and those that emerged during the course of the research.

The study primarily highlights the effectiveness of VR as a potent research tool for examining and modeling cognitive and communicative processes, particularly in understanding linguistic transformations in speaker behavior, including deictic behaviors. VR's success in this regard is attributed to its ability to replicate experimental conditions with high precision, standardize variables, and manipulate independent factors: scene configurations, object placements, and reference points. This flexibility allows researchers to explore complex interactions that traditional experimental paradigms may not fully capture, offering deeper insights into human communication and cognitive processes dynamics.

Moreover, the analysis of speaker behavior through verbal elements, such as adverbs, verbs, and other temporally relevant linguistic units, reveals the emergence of distinct temporal orientation models. These include chain orientation, orientation to shared memories, and orientation to an undefined previous scene, each providing a framework for understanding how temporal dynamics are managed within VR contexts. In brief, the implications of these findings are profound for the development of human-machine interfaces (HMI) and improvements to existing ones, as they pave the way for creating more natural and intuitive systems that align closely with human temporal perceptions. Enhancing user engagement and immersion through such interfaces can significantly improve the overall user experience in virtual environments, making interactions more seamless and realistic.

The obtained models of temporal orientation, based on temporal coordinates and the communicative orientation of speakers collectively form a temporal axis.

This study identifies three distinct temporal axes guiding communicative interaction within VR: the VR temporal axis, the episodic temporal axis, and the temporal axis of reality. These axes can intersect, replace each other, or run parallel without interfering with each other during communication. The ability to simultaneously perceive and interact with different temporal axes allows for the creation of a dynamic and interconnected temporal experience, which is important for the development of sophisticated HMI systems.

Thus, the unique nature of these temporal axes, as integral components of more complex deictic and temporal behavior models in VR, underscores the significant impact of VR on speakers' communicative behavior, even under standard VR conditions. It is evident that the nature of VR substantially shapes both communicative and more narrowly deictic behavior, despite similarities with behavioral patterns observed in the real world.

Ultimately, the primary objective of this study has been successfully achieved, establishing a coherent, communication-oriented coordinate system and temporal orientation known as virtual-temporal deixis. This system vividly portrays temporal models of deictic behavior with their specificity and uniqueness, particularly those observed within the VR environment.

Beyond its role as a methodological instrument, VR should also be regarded as a transformative mechanism of communication and learning. The reconfiguration of temporal deixis within immersive environments demonstrates how users adapt to new patterns of temporal reference, thereby reshaping their communicative behavior. This implies that VR is not limited to simulating real-world temporal dynamics but rather generates novel frameworks of temporal experience that can be effectively integrated into human–machine interaction systems, as well as in pedagogical practices. In this sense, the study provides not only theoretical insights but also outlines practical directions for employing VR in education, training, and communicative technologies, where the ability to manage complex temporal structures is crucial.

Finally, to validate these models and data as fundamental aspects of virtual-temporal deixis, further meticulous experiments with varied parameters and tasks should be conducted. Consequently, these models can be subjected to testing and potentially confirmed based on empirical evidence, thereby reinforcing their validity for development of human-machine interfaces (HMI) and its improvements.

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МОДЕЛИ ВРЕМЕНСКЕ ОРИЈЕНТАЦИЈЕ ГОВОРНИКА У ВИРТУЕЛНОЈ РЕАЛНОСТИ И ЊИХОВ УТИЦАЈ НА СИСТЕМЕ СУЧЕЉАВАЊА ЧОВЈЕКА И МАШИНЕ

Резиме

Овај рад бави се моделима који се тичу временске оријентације говорника током комуникације у оквиру виртуелне реалности (ВР). Појам виртуелне реалности означава једно окружење које се ствара уз помоћ компјутерских технологија и техничког апарата. Данас се виртуелна реалности сматра једним од експерименталних поља или истраживачких методологија. Ово истраживање обављено је путем експеримента, при чему је анализирано 725 реакција потеклих од 24 учесника, у којима су идентификоване временске деиктике (ријечи или изрази чије значење зависи од контекста) које означавају временску блискост или удаљеност, што је помогло да се опишу модалитети временске оријентације унутар виртуелне реалности. У овом истраживању тежи се темељној обради сложености модела временске оријентације унутар разних окружења виртуелне реалности, при чему се обраћа посебна пажња на њихову улогу у обликовању комуникације и оптимизовања интеракције човјека и машине (ЧМИ). Путем детаљног експерименталног оквира заснованог на виртуелној реалности ова студија проучава когнитивне и комуникационе процесе, разоткривајући дистинктивне моделе временске оријентације и њихове варијације, које су под утицајем ванлингвистичких фактора. Наведена анализа даље наглашава временску оријентацију говорника у виртуелној реалности, која се означава као виртуелно-темпорална деикса и твори један јединствени комуникативно-индикативни координатни систем.

Резултати потврђују вриједност виртуелне реалности као једног снажног оруђа у истраживању когнитивне и комуникационе динамике, уз механизме језичке трансформације. Поред тога, подаци до којих се дошло током истраживања нуде једну теоријску основу за развој система интеракције човјека и машине који су ближи људском поимању времена, јачајући природније и интуитивније корисничке интеракције.

▸ ***Кључне ријечи***: виртуелно-темпорална деикса, деиктике, модели, виртуелна реалност, понашање говорника, оријентација, интеракција човјека и машине (ЧМИ).

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