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FIRST STEPS TOWARDS A METADATA SCHEME FOR AUDITORY COGNITION EXPERIMENTS IN VIRTUAL REALITY

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ABSTRACT

Virtual reality and mixed reality (VR/MR) systems have the advantage to conduct audiovisual psychological experiments in a reproducible environment with great experimental control. In the field of auditory cognition, where acoustics and cognitive psychology are in constant interplay, the lack of design guidelines limit the use of VR/MR for conducting experiments. Another challenge lies in the VR/MR specific terminology that might be unknown to researchers from other fields. This study highlights design needs, system requirements, and challenges from an interdisciplinary viewpoint, including acoustics, cognitive psychology, and VR/MR. We analysed metadata from the experimental design, the development, and evaluation process from selected auditory cognition experiments conducted in VR by collecting psychology-related, video-related, and audio-related parameters. All parameters were found to be important features of the production, transmission, and reproduction part of an experiment. At the same time, it was possible to define a baseline for the system requirements from a technical viewpoint regarding hardware and software. This work presents the first steps towards a design guideline for specific auditory cognition experiments in VR.

Keywords: *metadata, auditory cognition, virtual reality, acoustics, psychology, database, RDM.*

1. INTRODUCTION

Until recently, the majority of experiments in the field of auditory cognition has been carried out in simplified laboratory environments, thus limiting the complexity of the scene. Since virtual reality (VR) software and hardware has become easily available in the last years, more and more scientific experiments can be carried out in virtual environments (VE) with a high degree of controllability. Virtual reality environments provide the possibility to carry out experiments in complex or close to real life environments. One of the main challenges when it comes to conducting auditory cognition experiments in VR, is the difficulty to incorporate different requirements from all disciplines involved, namely acoustics, cognitive psychology, and computer science. Nevertheless, apparent advantages of interdisciplinary research are the synergetic effects which cannot be achieved by a single discipline.
Although VR is used in psychology as well as in acoustics as an experimental tool [1-4], the lack of design guidelines poses a major challenge for experiments when carried out in an interdisciplinary field of research. Additionally, augmented VR, mixed VR and VR technologies itself deal with a wide range of research topics within their own discipline, e.g. the development of hardware and software, user experience, or human-computer interaction. The aim of this study is to analyse the scientific terms used by each discipline and collect discipline-specific metadata from experiments. This way, key aspects for conducting auditory cognition experiments in VR are identified and summarized in this paper.

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2. METHODOLOGY

In order to collect information and relevant metadata from auditory cognition experiments in VR, we developed a questionnaire in the form of a table with relevant experimental aspects identified in a prior study [5]. Two categories form the basic structure, namely dependent and independent variables of an experiment. Each category is divided into subgroups, leading to a detailed collection of methodological and technological aspects of the experiment. Additionally, information on the investigated paradigm and evaluation methods is collected. Table 1 shows the categories and subgroups of the questionnaire.

Table 1. Categories and subgroups of the questionnaire to collect metadata from auditory cognition experiments in VR.

Category		**Subgroups**
Independent Variables	Scenario	scene
		task, paradigm
		subject
	Technology	IVE engine
		audio representation
		visual presentation
		device
		user interaction
	Evaluation	spatial presence
		social presence
		immersion
		authenticity
		plausibility
		media quality
		audio quality
		avatar evaluation
Dependent variables	Measures	physiological measure
		cognitive response
	Metadata	additional data
	Signals	recorded signals

Each category can be addressed at different levels of detail, depending on the experiment. In the following, each category is explained briefly. When used in further studies, it is highly recommended to include the category description to support researchers when providing the data.

Scenario. The description of the scenario should provide an overview on the paradigm that is used in the experiment. By describing the task and the subject, it is possible to classify the experiments by the paradigms investigated.

Technology. The hardware and software used to conduct the experiment has to be thoroughly described by audio- and video-related parameters as well as specifications from the hardware used. Additionally, the VR hardware, e.g. the interactive virtual environment engine (IVE), the user device, or the possibility to interact in the IVE, have to be indicated.

Evaluation. VR can be evaluated by established questionnaires addressing the topics of presence. Additionally, the quality (or also plausibility and authenticity) are key concepts when it comes to the evaluation of audio quality as a measure of realism of the sounds. Authenticity refers to the case when a reference is available, plausibility to the case where no reference is available.

Measures. In this section, the measured data should be described, addressing physiological, cognitive, and behavioral measures.

Metadata. In this section we asked, if the researchers conducting the experiment, collected additional data that was not covered by the previous categories before.

Signals. Here, we explicitly asked for the recorded signals during the experiment, related to audio, video, or other data.

We collected information from seven interdisciplinary research projects, each carrying out at least one experiment in the field of auditory cognition. Each research group filled out the table. All research projects are carried out in an interdisciplinary context, where at least two out of three disciplines are involved. To ensure a certain degree of consistency, one of the disciplines always being acoustics. From the table, we derived audio-, video-, and psychology-related parameters and terms. Parameters and terms of each category can then be used to design and describe an auditory cognition experiment beginning from production, to transmission, and reproduction of the experiment. The work flow is shown in Fig. 1.

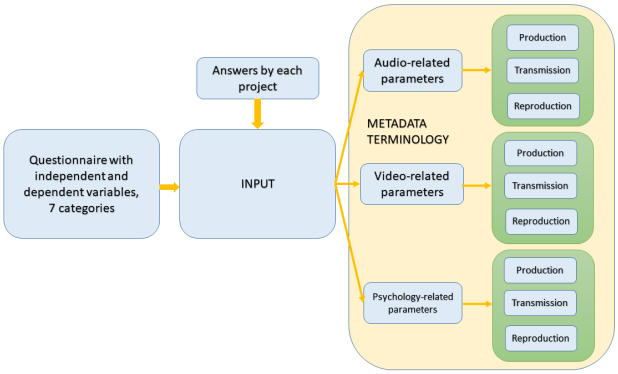

Figure 1. Block diagram of the data collection process to obtain metadata terminology.

3. DATA COLLECTION

The collected data was sorted and evaluated according to the three disciplines, acoustics, cognitive psychology, and VR. The aim was to extract parameters that are relevant for the experimental design process, considering both methodological and technical aspects. Each term can be complemented with a brief descriptor for better understanding, or classic examples could help researchers navigate their way through the experimental design procedure.

3.1 Acoustics

Audio-related parameters were identified with respect to the following categories: hardware, topology, sources, filters, reproduction software, HRTFs, signal types, virtual acoustic environment specifications.

- HRTFs:
  - format,
  - spatial resolution,
  - rendering technique,
  - head-tracking,
  - type,
  - individualization method,
  - equalization method
- Impulse response:
  - format,
  - type,
  - # channels
- Virtual acoustic environment:
  - format
  - application
  - open source
- Hardware specifics:
  - soundcard,
  - headphone type
  - microphones
  - frequency range
  - frequency response
  - speaker types
  - A/D, D/A converter specifications
- Room acoustic parameters of virtual scene

3.2 Video/Virtual Reality/Visuals

Video-related parameters were identified, where a special emphasis was put on CGI-, video-, and hardware-related parameters.

- CGI specifics:
  - General avatar geometry resolution (polygons / points / voxel size)
  - texture resolution
  - rigging and animation approach
  - tracking - full body motion capture / controller driven motion, etc.
  - implementation of lip-sync
  - reconstruction of facial expression
  - visualization technique: triangle, point rasterization, ray-casting, etc.
  - lighting, relighting
- Video specifics:
  - bitrate
  - resolution
  - data format
  - encoding settings
  - projection schemes
  - bit depth
  - color format
  - stitching artifacts
- Hardware specifics:
  - field of view
  - refresh rate
  - viewpoint degrees of freedom
  - brightness
  - contrast
  - inter-eye distance

3.3 Psychology

Psychology-related parameters were identified for the specific categories of data evaluation, experimental reproducibility, and participant specifications. In order to strive towards a better reproducibility of experiments, this list provides features that are relevant when designing and conducting experiments in cognitive psychology.

- Evaluation:
  - statistical tests used
  - questionnaire and scales
  - task performance
  - behavioral measurements
  - validation of evaluation methods
  - psychometric data
- Participant specifications:
  - age, gender
  - expertise
  - vision test
  - instruction setup: how, by whom
- Experimental procedure:
  - task specifics: possible movement, pictures from scenes, etc.
  - challenges before, during, and after the experiment

4. DESIGN GUIDELINE

The aim of a design guideline is (1) to provide an overview on the relevant aspects of the experiment, (2) to support the researchers to come up with a clear and achievable plan to meet their objectives, and (3) to assure a certain quality by providing basic technological and methodological requirements. When designing an auditory cognition experiment in VR, the questionnaire from Tab.1 can support the researcher by providing an overview of relevant technological and methodological aspects. In the second step, the audio-, video-, and psychology-related parameters provide a guideline for considering relevant features that are important when conducting an auditory cognition experiment. The parameters are important for the three phases of the experiment, namely the production part, when the experiment is set up and the stimuli are prepared; the transmission part, where audio-visual frameworks are merged; and for the reproduction part, where the stimuli are presented to the subject and the signals are recorded for further evaluation.

5. CONCLUSION

In this work, we presented a collection of terms used in auditory cognition experiments in VR. which is not intended to be complete by any means. When designing an experiment, the collection can support the interdisciplinary work flow by providing important terminology from the related fields, in this case acoustics, cognitive psychology, and VR. Furthermore, it can be used to ensure a better reproducibility of the experiment by providing essential metadata. The benefit of recording metadata is the improved usability of data sets and reusability of design setups. The data collection can be extended in the future and serve as a guide, for e.g. finding adequate evaluation methods, when a specific task is investigated.

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