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**Effects of a standardized distraction on caregivers' perceptive performance
with avatar-based and conventional patient monitoring: a multicenter
comparative study**

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Abstract: Patient monitoring requires constant attention and may be particularly vulnerable to distractions, which frequently occur during perioperative work. In this study, we compared anesthesia providers' perceptive performance and perceived workload under distraction for conventional and avatar-based monitoring, a situation awareness-based technology that displays patient status as an animated patient model. In this prospective, multicenter study with a within-subject design, 38 participants evaluated scenarios of 3- and 10-s durations using conventional and avatar-based monitoring, under standardized distraction in the form of a simple calculation task. We quantified perceptual performance as the number of vital signs correctly remembered out of the total of 11 vital signs shown. We quantified perceived workload using the National Aeronautics and Space Administration Task Load Index score. Anesthesia providers remembered more vital signs under distraction using the avatar monitoring technology in the 3-s scenario: 6 (interquartile range [IQR] 5-7) vs. 3 (IQR 2-4), $p < 0.001$, mean of differences (MoD): 3 (95% confidence interval [95% CI] 1 to 4), and in the 10-s monitoring task: 6 (IQR 5-8) vs. 4 (IQR 2-7), $p = 0.028$, MoD: 1 (95% CI 0.2 to 3). Participants rated perceived workload lower under distraction with the avatar in the 3-s scenario: 65 (IQR 40-79) vs. 75 (IQR 51-88), $p = 0.007$, MoD: 9 (95% CI 3 to 15), and in the 10-s scenario: 68 (IQR 50-80) vs. 75 (IQR 65-86), $p = 0.019$, MoD: 10 (95% CI 2 to 18). Avatar-based monitoring improved anesthesia providers' perceptive performance under distraction and reduced perceived workload. This technology could help to improve caregivers' situation awareness, especially in high-workload situations.

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Effects of a standardized distraction on caregivers' perceptive performance with avatar-based and conventional patient monitoring: A multicenter comparative study.

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Author contributions

Juliane Pfarr: This author helped design the study, collect the data, analyze the data, write the article and approved the final version.

Michael T. Ganter: This author helped collect the data, write the article and approved the final version.

Donat R. Spahn: This author helped design the study, write the article and approved the final version.

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Abstract

Purpose

Patient monitoring requires constant attention and may be particularly vulnerable to distractions, which frequently occur during perioperative work. In this study, we compared anesthesia providers' perceptive performance and perceived workload under distraction for conventional and avatar-based monitoring, a situation awareness-based technology that displays patient status as an animated patient model.

Methods

In this prospective, multicenter study with a within-subject design, 38 participants evaluated scenarios of 3- and 10-second durations using conventional and avatar-based monitoring, under standardized distraction in the form of a simple calculation task. We quantified perceptual performance as the number of vital signs correctly remembered out of the total of 11 vital signs shown. We quantified perceived workload using the National Aeronautics and Space Administration Task Load Index score.

Results

Anesthesia providers remembered more vital signs under distraction using the avatar monitoring technology in the 3-second scenario: 6 (Interquartile range [IQR] 5-7) vs. 3 (IQR 2-4), $p < 0.001$, mean of differences (MoD): 3 (95% confidence interval [95%CI] 1 to 4), and in the 10-second monitoring task: 6 (IQR 5-8) vs. 4 (IQR 2-7), $p = 0.028$, MoD: 1 (95%CI 0.2 to 3). Participants rated perceived workload lower under

distraction with the avatar in the 3-second scenario: 65 (IQR 40-79) vs. 75 (IQR 51-88), $p=0.007$, MoD: 9 (95%CI 3to15), and in the 10-second scenario: 68 (IQR 50-80) vs. 75 (IQR 65-86), $p=0.019$, MoD:10 (95%CI 2to18).

Conclusion

Avatar-based monitoring improved anesthesia providers' perceptive performance under distraction and reduced perceived workload. This technology could help to improve caregivers' situation awareness, especially in high-workload situations.

Keywords

Situation awareness; Patient Monitoring; Computer-assisted, diagnosis; Visual Patient.

Glossary of Terms

CO ₂	Carbon Dioxide
PASAT	Paced Auditory Serial Additions Test
NASA	National Aeronautics and Space Administration
TLX	Task Load index
MoD	Mean of Differences
95%CI	95% Confidence Interval
IQR	Interquartile Range

Introduction

In the work environment of perioperative and intensive care, physicians and nurses are constantly sidetracked from their work by external and self-induced distractions.[1-5] Distractions have various characteristics that merge with each other. A non-exhaustive list includes acoustic disturbances, such as those caused by background music or false positive audio alarms, cognitive distractions caused, e.g., by irrelevant background communication, and emotional distractions caused by stimuli that provoke an emotional response. Distractions may affect vigilance, situation awareness, and decision making.[1-3,6-8] The neuropsychological basis of these effects is that distractions lead to attention consumption, i.e., they bind cognitive capacity, which is then unavailable for relevant tasks. Short-term memory and prospective memory are particularly susceptible.[4,9] Several experiments have shown that distractions reduce performance during tasks and increase perceived stress levels and workload.[9-13]

Patient monitoring occurs at the critical interface between the physical quantities measured in the patient and the sensorium and cognition of the human decision-makers.[6,8,14] Previous research has found that state-of-the-art patient monitoring shows deficits in information transfer due to its design.[15] For instance, to transmit vital sign data, patient monitors make use of a multitude of individual curve-forms and numerical values, many of which have similar ranges, e.g., pulse rate, blood pressure and oxygen saturation can all “be” 96. Humans can only read numbers if they view them with foveal or sharp vision, which they can only direct at one number at a time. To get a complete “picture” of a patient's situation, care providers must read all numbers and cognitively integrate this data before they can derive meaning.[16] This complex task may be especially challenging in time-critical

situations when distractions are also numerous. One way to mitigate distractions might be to present the data in a more intuitive or useable way than through numbers and waveforms. Visual Patient technology,[17] a situation awareness-based technology that presents vital sign information as an animated avatar of the monitored patient, could be one approach to accomplishing this. In a previous study, we found that, compared to conventional monitoring during short viewing times, this technology improved perceptual performance and diagnostic confidence while reducing perceived workload. Furthermore, users have considered the technology to be intuitive, easy to learn, and helpful.[18]

In this study, we aimed to evaluate how these advantages behave under standardized distraction. We chose to use short 10- and 3-second scenarios on the basis of previous research. Loeb found that during induction of anesthesia, which is a period of high anesthesiologist workload, residents glance toward monitors to gather data rather than scan displays.[19] Another study reported that anesthesia providers look at the patient monitors in one- to two-second glances during routine operations.[20] Also, the literature has for some time been calling for monitoring solutions that provide situation awareness with high diagnostic certainty quickly and without compromising attention and workload.[7,14,15]

We hypothesized that avatar-based monitoring would allow anesthesia providers to perceive more information with reduced perceived workload when distracted than conventional patient monitoring.

Methods

This study received a declaration of no objection from the Zurich Cantonal Ethics Commission (Business Administration System for Ethics Committees No. 2017-00795, issued on October 23, 2017). All participants took part without financial compensation and signed informed consent for the use of their data for research.

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Description of Visual Patient Technology

The version of the avatar used in this study can display the 11 most frequently monitored vital signs: pulse rate, blood pressure, oxygen saturation, electrocardiogram ST-segment, central venous pressure, respiratory rate, tidal volume, expiratory carbon dioxide concentration, body temperature, brain activity, and neuromuscular relaxation.

The technology pre-processes the numerical values into the categories "too low", "normal", or "too high" and displays this information according to principles of logic and user-centered design, so that the avatar's appearance corresponds to the expected phenomena in the real patient that it represents.[7,21,22] For example, according to the measured pulse rate, the avatar's body may pulsate slowly, normally or quickly, representing the pulse wave passing through the real patient's body. As another example, according to the measured oxygen saturation, the avatar may display natural or purplish skin color representing regular oxygen saturation or hypoxemia. According to the measured expiratory carbon dioxide (CO₂) concentration, the avatar may exhale a small, regular, or large CO₂ cloud, representing the exhaled CO₂ concentration. The three key features of the avatar

are pre-processing of data, direct display of information, and representation of vital signs in multiple visualizations, e.g., care providers may assess respiratory rate from the breathing rate of the lungs as well as the formation rate of the carbon dioxide cloud. These features translate the multitude of numerical values into an animated model of the patient's situation that care providers can evaluate and memorize at a glance, without first having to deduce meaning from underlying numerical data. The translation of the vital signs from the numerical data into the avatar model takes place in real time as with conventional monitoring. Supplementary Video 1 explains all visualization used in Visual Patient technology.

Study participants

We conducted this study at two medical centers with anesthesia providers from the University Hospital Zurich and the Cantonal Hospital Winterthur. All participants took part in the study on a regular working day. They were asked to participate and relieved from their duties for the duration of their participation. We included participants according to a predefined inclusion plan, which served to ensure that in the two hospitals a comparable number of participants from the same occupational groups and with the same gender participated. This enabled us to conduct a study that was representative of the health care providers working in the anesthesia departments and reduced the risk of over- or under-representation of a particular occupational group or gender. The inclusion plan required that in each hospital at least two senior physicians, three residents, and three nurses evaluate both scenarios. The odd number of residents and nurses in each scenario did not allow for a 1:1 gender distribution. However, we still aimed for a well-balanced gender distribution for all scenarios, occupational groups, and hospitals. If, in a hospital,

more than the predefined minimum number of participants was available on the study days, we included the additional participants.

We included the participants on several days in Zurich and Winterthur. Beginning in Zurich, participants 1-8 assessed the 10-second scenario. Then, participants 9-22 evaluated the 10-second scenario in Winterthur. This group had 14 participants instead of only eight in the other groups because they were institutionally planned to participate in the study, and accordingly available on the days we tested the 10-second scenario in Winterthur. On a consecutive day, participants 23-30 evaluated the 3-second scenario in Winterthur, and finally, participants 31-38 evaluated the 3-second scenario in Zurich.

Study design

Study procedure

We conducted this study as a computer-based laboratory study. The volunteers sat with a data collector in a quiet room, where they could watch and evaluate monitoring scenarios undisturbed. At the beginning of each data collection session, participants completed a personal data questionnaire and watched a 6-minute video explaining the avatar-based monitoring technology (Supplementary Video 1). Also, the participants familiarized themselves with the layout of the conventional patient monitor used in this study. For the conventional scenarios, we used simulated scenarios, which were represented by a simulator emulating a GE Datex Ohmeda monitor (General Electric Company, Boston, MA, USA) using the app SimMon (Castle 2 Andersen ApS, Hillerød, Denmark). For the highest possible degree of realism, we highlighted all pathological values in yellow and played an acoustic alarm. There was also a beep for each heartbeat, and the pitch of the beep was

dependent on the SpO2 value, as is standard in conventional monitoring.

Supplementary Video 2 shows the original scenarios used in this study with multiple vital signs represented at the same time.

Figure 1A-C provides a graphic example of the study setup, the interfaces of the two patient monitoring technologies and the Paced Auditory Serial Additions Test (PASAT).[23] We used the PASAT to simulate a standardized distraction. The test persons learned about the PASAT after familiarizing themselves with the two monitoring technologies. In the PASAT test, an audio recording is played, which gives a new one-digit number every 2 seconds. The last two numbers played back have to be added by the test person, and the result has to be named aloud. This test requires different cognitive resources: listening, understanding, calculating, and speaking and allows for identical test conditions for all test persons. We explained the PASAT in theory and practiced it with the test persons until they had learned to add a series of numbers without errors. After learning the PASAT, each participant rated four videos in sequence. We first played the scenario without PASAT, then twice with PASAT, and finally again without PASAT. These videos showed the same scenario under four different conditions, i.e., as a conventionally monitored scenario with and without PASAT and as an avatar scenario with and without PASAT. We used two video sequences, which we exchanged after each subject. Sequence 1 started with an avatar scenario, sequence 2 with a conventional scenario. Figure 1D explains this procedure. The alternating order of the scenarios between the two technologies and the multiple questions of the National Aeronautics and Space Administration (NASA) Task Load index (TLX) questionnaire,[24,25] which participants answered after each of the four videos served to hide that they watched the same scenario, albeit under different conditions and technologies, several times.

This procedure allowed us to test the performance of each participant with the different technologies with and without distraction, which allowed for intra-individual comparisons. After the 3- or 10-second intervals, based on the Situation Awareness Global Assessment Tool,[7-26] the computer screen darkened and the volunteers recited the vital signs they remembered aloud. The four choices available to the participants were the nominal scale-level measurement options: "too low", "safe", "too high", and "no recall". The participants did not have to remember the exact numerical values. The data collector entered the responses and asked for the vital signs not yet mentioned. We collected all data for this study electronically using an iPad-based data collection tool (Apple Inc., Cupertino, CA, USA).[27]

Scenarios

In this study, we evaluated two different scenarios, one with a duration of 10 seconds and one with a length of 3 seconds. Both scenarios showed 11 vital signs in total: pulse rate, arterial blood pressure, oxygen saturation, central venous pressure, electrocardiogram ST-segment, respiratory rate, tidal volume, expiratory CO₂ concentration, body temperature, brain activity, and neuromuscular conduction. The 3-second scenario showed a hemorrhagic shock, characterized by "too high" pulse and respiratory rate, and "too low" blood pressure, central venous pressure, and body temperature. The 10-second scenario showed a case of intraoperative awareness, characterized by "too high" pulse rate, blood pressure, expiratory carbon dioxide concentration, and brain activity in a patient with deep neuromuscular relaxation. We played the monitoring scenarios back as video files (Supplementary Video 2) to ensure that all participants had the same study conditions. We also

recorded the PASAT sequence of numbers within these videos so that all participants experienced the exact same level of difficulty concerning distraction.

Outcome measures

The goal of this study was to quantify and compare the perceptual performance of anesthesia providers using two patient-monitoring technologies, conventional and avatar, under a standardized, simulated distraction.

The primary outcome variable was the number of vital signs that the participants correctly remembered under the two monitoring technologies when observing under distraction. Secondary outcomes included the comparison of participants' perceptual performance using the two technologies without distraction and perceived workload under the two technologies with and without distraction.

Online survey

To find out how frequent anesthesia providers estimated distractions to be during their work, we asked each participant to complete an online survey. In this survey, we asked respondents to rate the statement: "Distractions occur frequently during my daily work in the operating theater" on a five-point Likert scale from "strongly disagree" to "neutral" to "strongly agree."

Statistical analysis

To evaluate whether the groups in the two study centers were comparable, we used Fisher's exact test and Mann-Whitney U test as appropriate for the data.

We used the Wilcoxon signed rank test to find out whether the sample median of the ratings to the online survey statement significantly differed from neutral.

We assessed group differences between the avatar and conventional monitoring by paired t-test for normally distributed data or by Wilcoxon signed rank test for non-normally distributed data. Normality was assessed with the Shapiro-Wilks test and visual inspection of quantile-quantile plots of dependent variables. We express the distribution of variables using medians and interquartile ranges (IQR) regardless of normality. To complement traditional significance testing, we report effect sizes as means of differences (MoD) with 95% confidence intervals (95%CI).

We performed the statistical analyses and created the figures in GraphPad Prism 8.1.1. (GraphPad Software Inc., CA, U.S.A.). In this study, we considered p-values of <0.05 as statistically significant. We calculated all p-values and 95%CI two-tailed.

Sample size

We based the sample size planning for this study on the standard deviation (0.81) found in a pilot study with six participants and assumed a clinically relevant difference of one perceived vital sign. The estimated sample size for a paired t-test with a power of 80% at a significance level of 5% was 8 participants per scenario. To achieve this level of significance and statistical power in each center and for both scenarios, we had to include at least 32 participants.

Results

We carried out the experiments for this study throughout two weeks at the end of September and the beginning of October 2018.

Study participants

In Winterthur, we recruited 22 participants; in Zurich, 16. None of the collected data was excluded. The groups were not different regarding occupational groups (proportion of senior physicians, residents and nurse anesthetists), gender, anesthesia experience and age. Table 1 outlines the participant and study characteristics in detail.

PASAT performance

The median performance achieved in the PASAT test in all instances, i.e., for the two technologies and viewing times, was correctly completing at least five out of the seven possible calculations and was not significantly different between the two monitoring technologies and viewing times. In the 3-second scenario, the median PASAT performance for conventional monitoring was 5 of 7 total achievable (IQR 4-6) and for avatar-based monitoring 6 of 7 total (IQR 5-6), $p=0.18$, MoD: 2 (95%CI -2 to 0.4). The median PASAT performance in the 10-second scenarios under the two technologies was 5 out of 7 possible calculations (IQR 4-6), $p=0.84$, MoD: 0.05 (95%CI -0.5 to 0.4).

Outcome measures

Avatar vs. conventional and no distraction vs. standardized distraction

The anesthesia providers remembered more of the 11 total vital signs in both viewing durations with and without distraction when monitoring with the avatar. The perceived workload with the avatar was lower in all scenarios except the 3-second scenario without distraction.

Standardized distraction reduced the number of vital signs correctly remembered by anesthesia providers with both monitoring technologies and with both viewing times. It increased the perceived workload in all scenarios except the 3-second avatar-based scenario. Table 2 outlines the summary statistics in detail. Figure 2 and Supplementary Figures 1 to 3 show the results at the participant level.

Online Survey

Thirty-six of the total 38 participants (95%) completed the online survey. Twenty-nine participants (80%) agreed or strongly agreed to the statement: "Distractions occur frequently during my daily work in the operating theater". The median response was 3 (Interquartile range 3-4, 0=strongly disagree, 1= disagree, 2=neutral, 3= agree, 4=strongly agree). The sample median was statistically significantly different from neutral, $p < 0.001$. Figure 3 shows a donut plot of these results.

Discussion

In this paper, we present the results of an experiment in which we investigated how a standardized distraction affects the perceptual performance of anesthesia providers during patient monitoring with conventional and avatar-based monitoring.

We used a recognized tool to simulate a standardized distraction, the PASAT, an arithmetic task.

The results showed that perceptual performance under distraction was significantly higher while perceived workload was lower with avatar-based monitoring compared to conventional monitoring after viewing times of 3 and 10-seconds. Improvement during short viewing times is relevant according to Endsley et al., who defined the goal of successful situation awareness design as the fastest possible transfer of relevant information with minimal cognitive effort.[7,15] Also, the results showed that the performance of the participants declined with both monitoring technologies under distraction. For example, in the 10-second scenario with either of the two monitoring technologies, the mean of differences was 3 vital signs (95%CI for conventional, 2 to 4; for avatar, 3 to 4).

Distractions are a safety-relevant factor in our daily working lives.[1-5] Previous review articles and individual experiments have shown that distractions reduce the performance of test persons in various tasks and therefore represent a potential danger in the health care system.[9-13] They represent a hole in Reason's Swiss cheese model of accident causation.[28] In the online survey conducted with the participants of this study, 80% of the anesthesia providers agreed with the statement: "Distractions occur frequently in my daily work in the operating theater." In a recently conducted quantitative/qualitative study, 88% of anesthesiologists agreed with the statement that factors related to human performance (e.g. fatigue,

distractions) can lead to important information being overlooked.[29] This study gives us experimental evidence that it is crucial both to avoid unnecessary distractions in the operating room as much as possible and, at the same time, to provide the anesthesiologist with the simplest-to-interpret monitoring possible.

Fewer perceived vital signs lead to reduced situation awareness among care providers, who need to be aware of what is currently happening in the situation and where it will shortly lead. Situation awareness comprises three stages: 1. perception, 2. comprehension, and 3. projection and is the basis for meaningful decision making. Only when all relevant elements in a system are perceived, understood and their implication for future of events are understood by a care giver can a meaningful decision be made.[6-8,30] As in aviation, where most accidents are the result of inadequate situation awareness on the part of the flight crew, severe complications during anesthesia, in up to 80% of cases, have also been found to be caused by situation awareness errors.[31,32]

The dangers of distractions were recognized in commercial aviation in the 1980s as a result of aircraft accident analyses. Today, in the United States and the European Union, the "sterile cockpit philosophy" is a law. This rule requires aircraft pilots to perform only essential cockpit activities and communication in all demanding phases of the flight below the altitude of 10,000 feet.[5,33,34] Although an operating room may never become a truly sterile environment, it appears that especially in phases with increased stress levels, we should still try to reduce distractions and their impact. Since the early 1990s, several different research groups across the globe have attempted to transform vital sign display from numeric and waveform formats into a form of presentation that care providers can understand more easily.

Numerous studies have shown the benefits of such displays in terms of accuracy of

the diagnoses, time to diagnosis, and perceived workload.[7, 15, 17] An essential result, which was also instrumental for the development of our technology, was the realization that the presentation of information according to human anatomy, seemed particularly well suited for intuitive user understanding.[41] This finding corresponds both with findings of logic, according to which a good model should have a logical commonality with the reality it mirrors,[42] and with findings of situational awareness research, according to which information should be displayed in a so-called direct manner that does not require further processing in the users' brains.[7] Only now, at the end of the second decade of the 21st century, do anatomical or avatar-based technologies start to make it into everyday clinical practice. Examples include Hamilton's Dynamic Lung product (Hamilton Medical AG, Bonaduz, Switzerland), Masimo's Visual Alarm product (Masimo Corporation, Irvine, CA, USA), and Edwards Lifesciences Visual Decision Support product (Edwards Lifesciences Corporation, Irvine, CA, USA). The reasons for this long innovation cycle may include the economic strategies of the manufacturers, the stringent certification requirements of medical devices, the technically outdated internal structures of many modern monitors, the risk- and change-aversions of anesthesia providers, and their limited say in equipment purchase decisions. The proliferation of low-cost patient monitors has led to a commoditization of the market, which makes transforming innovations into product profit margins increasingly more difficult. The purchase decision-makers in healthcare systems are frequently far from front-end users and tend to follow the "good is good enough" paradigm. Anesthesia providers are very familiar with the current displays, even if they are inadequate from a human factors viewpoint, and anesthesia is already very safe. Therefore, measuring patient outcome improvements from new monitors became extremely difficult, and any

change to the already very safe status quo must take place with utmost caution. Measured outcomes will, therefore, have to focus on safety- and quality-critical cofactors, e.g., reductions of acoustic alarms or required cognitive demand, improvements in time-to-decision, usability, or user confidence. Still, with several products now available and Visual Patient technology, under development by one of the world's largest monitoring manufacturers, there is hope that a new, more user-centered era is finally dawning in the patient monitoring arena.

Limitations

This study has limitations. This study was conducted with participants sitting in front of a computer in a simulated environment. We cannot be sure that none of the test persons noticed that they were rating the same scenario several times. However, since we alternately used two different sequences, one with the avatar-based scenario first and one with the conventional scenario first, such effects would balance across the study between the two monitoring technologies. Still, it remains unclear how the results obtained relate to situations in a real operating room or intensive care unit environment with real distractions. A study in a full-scale simulator will help to answer this question on a closer level to reality and will follow shortly. Even though we did not randomly select the participants into this study, it is unlikely that there was a significant selection bias. We base this claim on the balanced nature of the sample, i.e., all occupational groups and genders were included at both study centers in comparable numbers. Seven participants (18%) of this study had participated in a previous study about Visual Patient technology.[17,18] Prior avatar exposure may have enabled improved performance compared to completely naive participants. However, as actively employed anesthesia providers, all of the participants had extensive experience in number- and waveform-based monitoring, which they had been practicing regularly for years.

Finally, Visual Patient technology has some inherent limitation. One limitation is the pre-processing of the vital sign data into categories, which results in a reduction of data accuracy, e.g., in the avatar, pulse rate can take on one of three individual states, i.e., “too low”, “normal”, or “too high”. In number and wave-form monitoring, it can take on about 300 individual states between 0 and 300 beats per minute.

Another inherent limitation of the Visual Patient version tested in this study is that it

cannot display trends. This is important because conventional patient monitors often have trend displays that clinicians use to detect changes over time. Here it is important to clarify that avatar-based monitoring is not intended to replace conventional patient monitoring. It aims to improve information transfer to human decision-makers in situations with frequent distractions, reduced cognitive resources, or a monitor positioned in the peripheral visual field.[1-5,9-13,43] As soon as a care provider has detected that a vital sign is outside its normal range, they may want to determine a more exact degree of deviation from the numerical value if deemed necessary.

Conclusions

This study provides empirical evidence that avatar-based monitoring could serve to increase the patient status awareness of the care providers under distraction above the level possible with today's state-of-the-art. This could be especially useful in high-workload situations in a busy and distracting operating room or intensive care unit environment. Furthermore, this study showed that distractions can reduce anesthesia providers' performance in perceiving patient status. It is, therefore, important to reduce distractions to a minimum during patient monitoring and to simplify information transfer from patient monitors to keep situation awareness and thus potentially patient safety at the highest possible level.

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Figure 1: A: The study setup. A participant looks at an avatar-based monitoring scenario. B: A conventional monitoring scenario as used in this study. C: Paced auditory serial addition test (PASAT). A voice utters one-digit numbers every two seconds. The participants add the last two numbers in their heads and name the result out loud (orange speech bubbles). D: The two sequences with which we played the scenarios to the test persons. We alternated the two sequences to minimize the effects of the order with which the scenarios were presented.

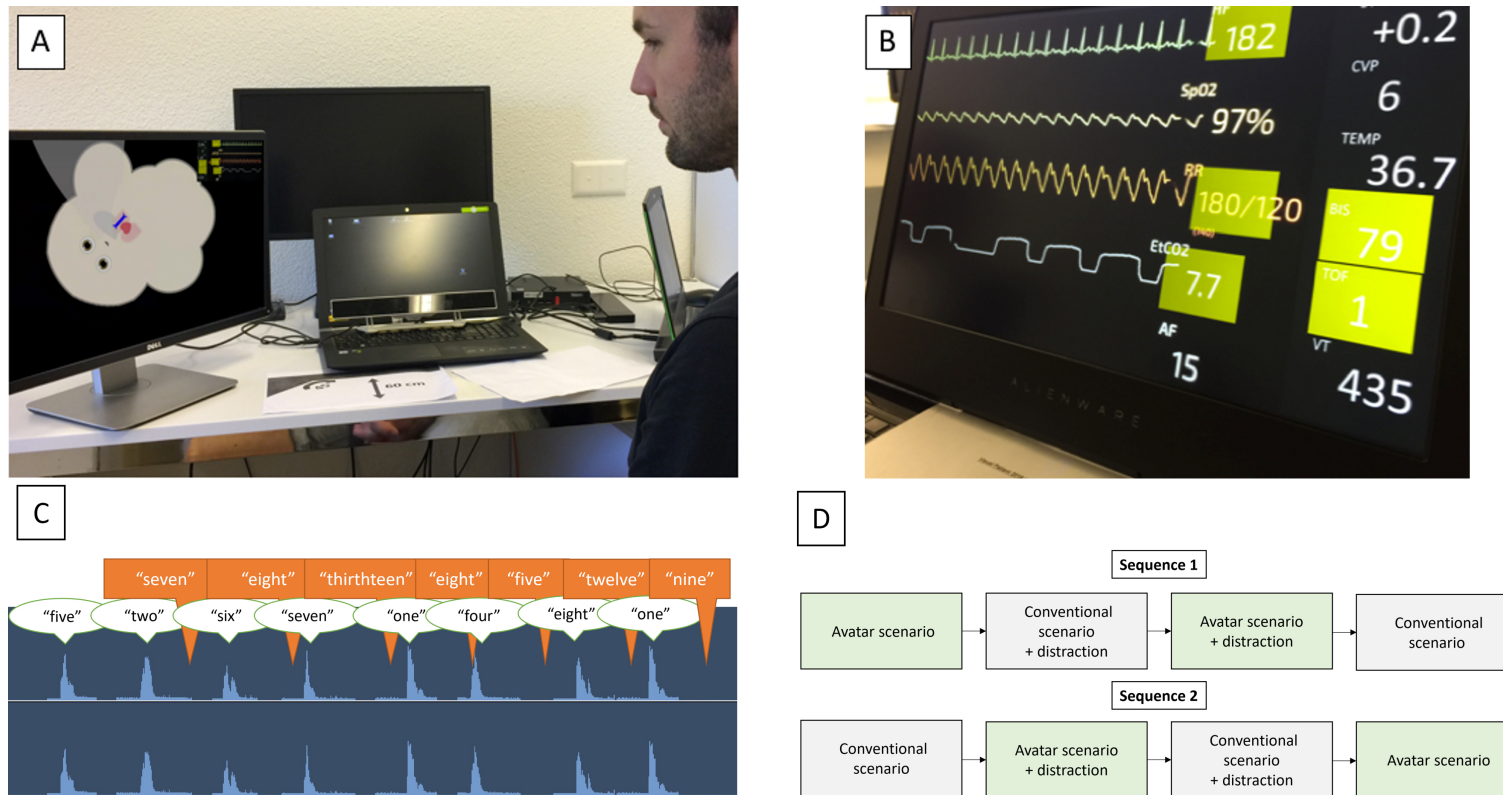


Figure 2: Comparison of the participants' perceptive performance and workload using the two monitoring technologies under distraction. Participants 1 to 8 and 31 to 38 were recruited at University Hospital Zurich and participants 9 to 30 were recruited at Cantonal Hospital Winterthur. The lines and the dotted lines represent the medians.

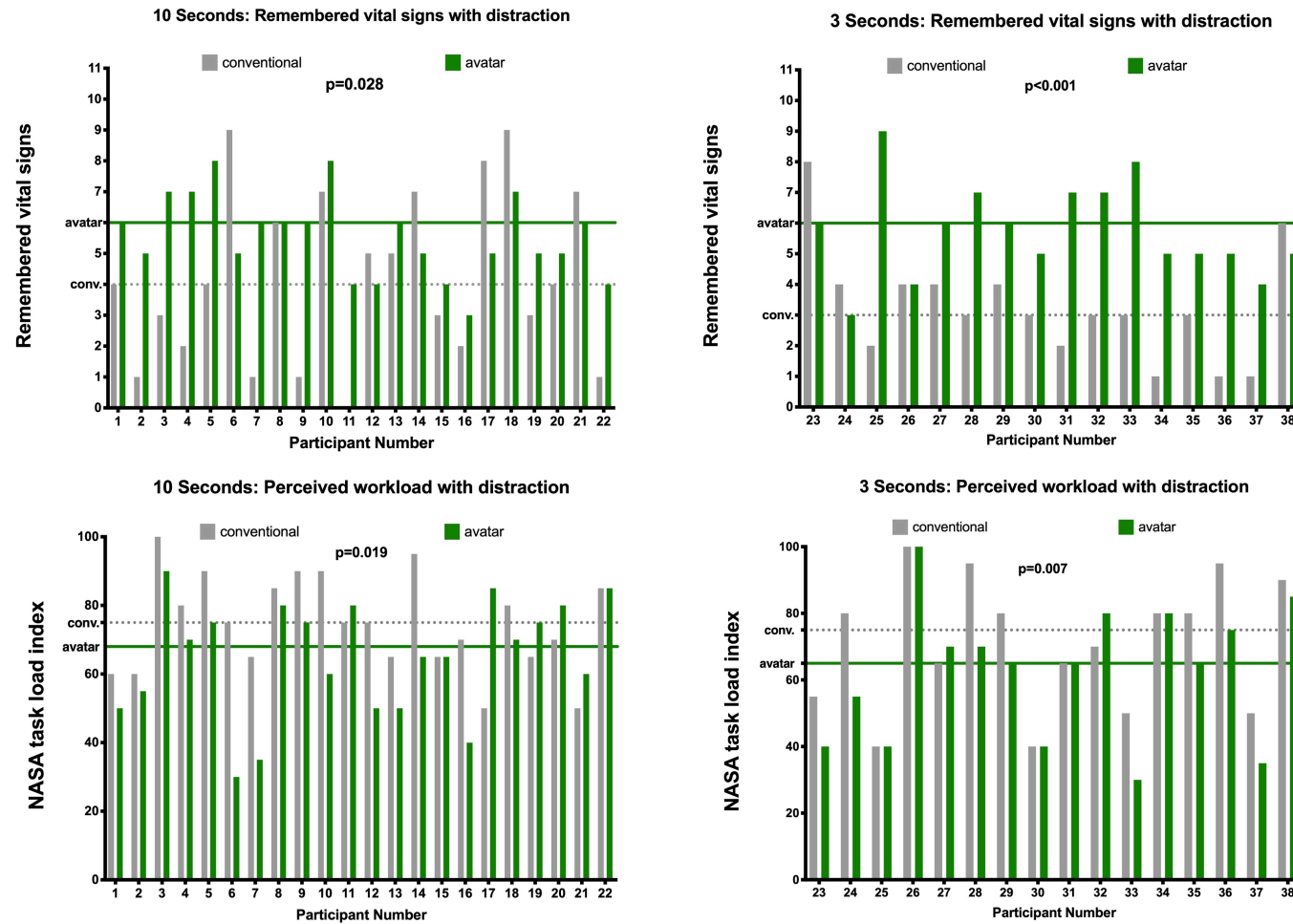


Figure 3: Presentation of the results of the online survey as donut plot with the number of participants who chose a particular category. We used the Wilcoxon signed rank test to find out whether the sample median was significantly different from neutral.

Distractions occur frequently during my daily work in the operating theater (n=36).

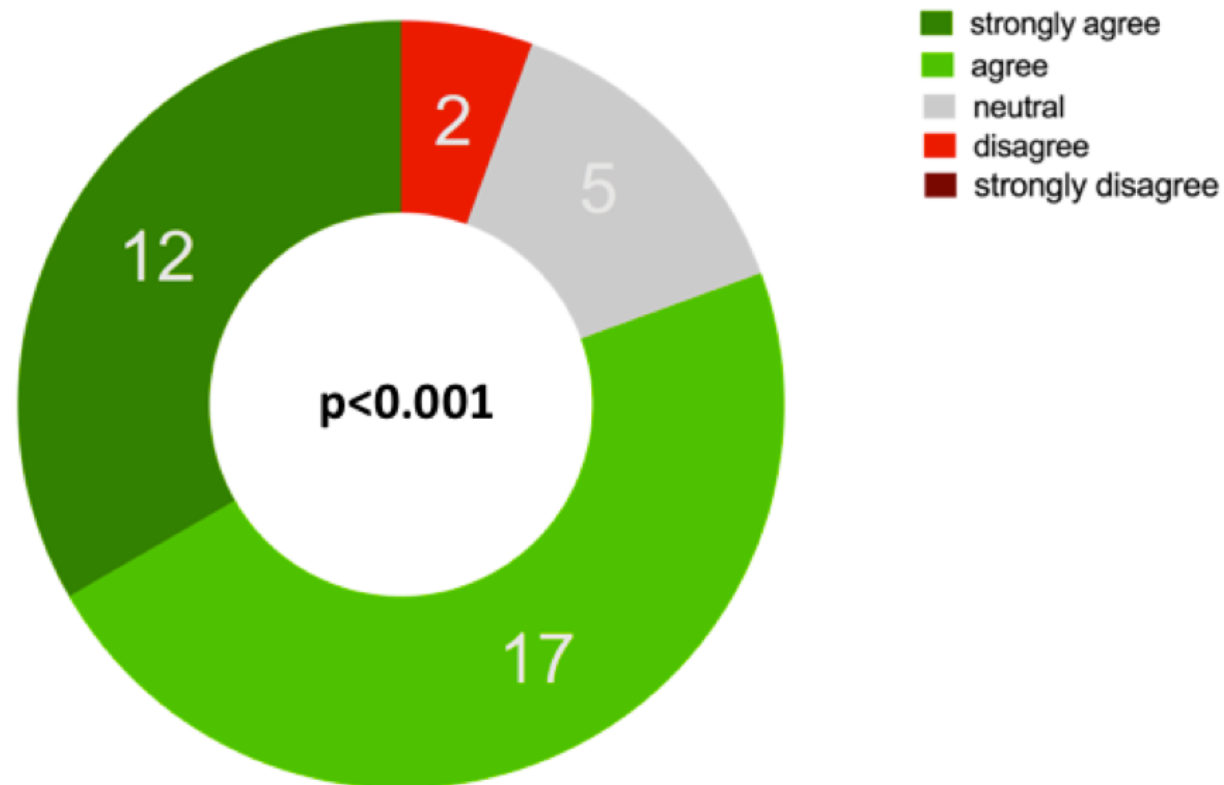


Table 1: Participant and study characteristics.

	Cantonal Hospital Winterthur (n = 22)	University Hospital Zurich (n = 16)	p value
Senior physicians (%)	6 (27)	4 (24)	p > 0.99
Residents (%)	7 (32)	6 (38)	p = 0.74
Nurse anesthetists (%)	9 (41)	6 (38)	p > 0.99
Female/male participants (%)	12 (55) / 10 (45)	9 (56) / 7 (44)	p > 0.99
Age of participants in years (%)	25 – 34: 7 (32) 35 – 44: 9 (41) 45 – 54: 5 (23) 54 – 65: 1 (4)	25 – 34: 9 (56) 35 – 44: 6 (38) 45 – 54: 0 (0) 54 – 65: 1 (6)	p = 0.084
Anesthesia experience of participants in years (%)	1 – 5: 5 (23) 5 – 10: 4 (18) > 10: 13 (59)	1 – 5: 8 (50) 5 – 10: 4 (25) > 10: 4 (25)	p = 0.21
Participants with prior avatar exposure (%)	7 (18)		
Study duration in days (period)	12 (September 24 th 2018 – October 5 th 2018)		

Table 2: Summary statistics. MoD = Mean of Differences. 95%CI = 95% Confidence Interval

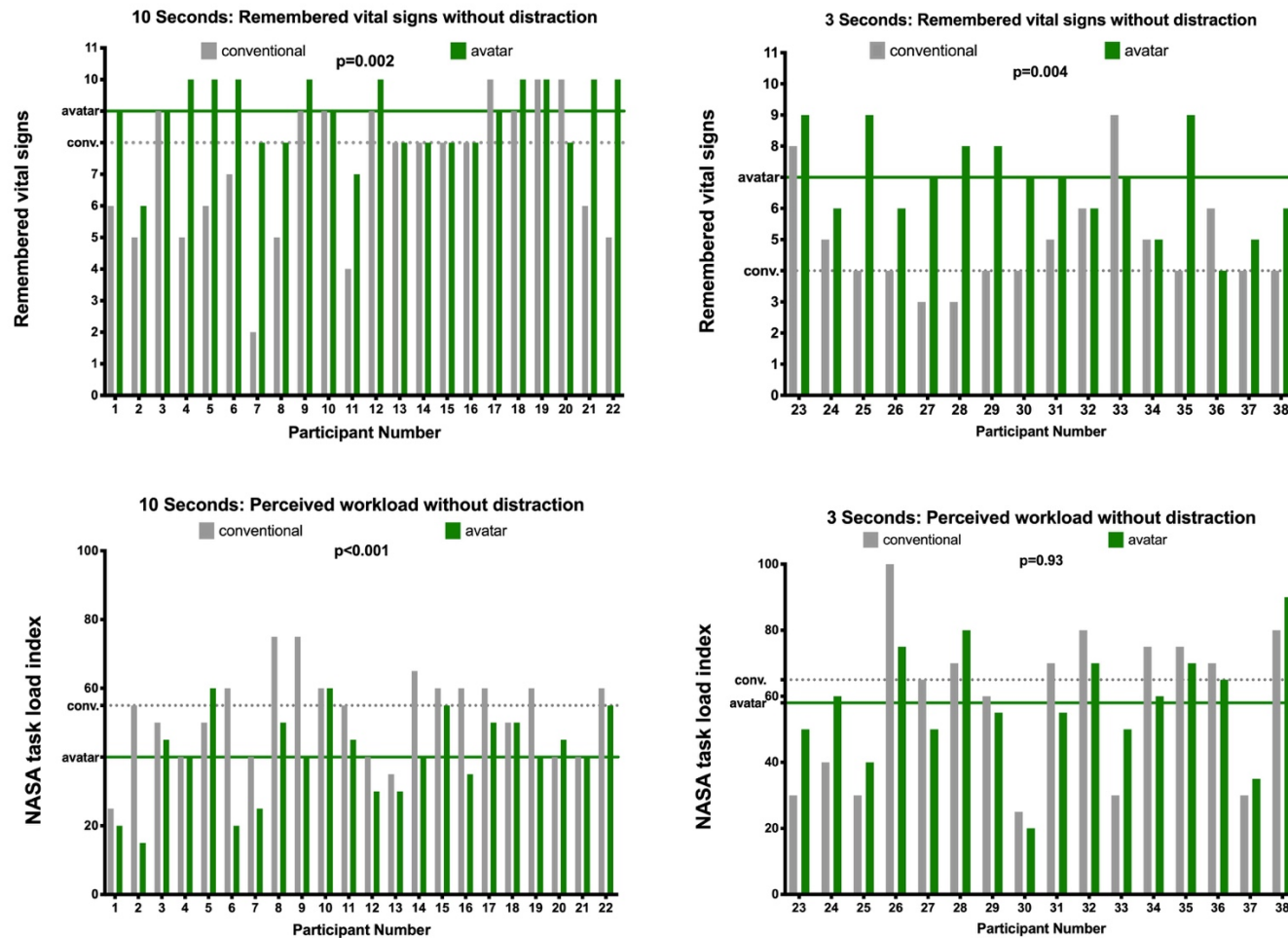
10-second Scenario (n=22)									
	Number of vital signs remembered (of 11 total) Median (IQR)					Perceived workload Median (IQR)			
	Avatar	Conventional	p value	MoD (95%CI)		Avatar	Conventional	p value	MoD (95%CI)
No Distraction	9 (8-10)	8 (5-9)	0.002	2 (0.7-3)	No Distraction	40 (30-50)	55 (40-60)	<0.001	12 (6-18)
Distraction	6 (5-8)	4 (2-7)	0.028	1 (0.2-3)	Distraction	68 (50-80)	75 (65-86)	0.019	10 (2-18)
p value	<0.001	<0.001			p value	0.20	<0.001		
MoD (95%CI)	3 (3-4)	3 (2-4)			MoD (95%CI)	4 (-11-3)	24 (19-30)		
3-second Scenario (n=16)									
	Number of vital signs remembered (of 11 total) Median (IQR)					Perceived workload Median (IQR)			
	Avatar	Conventional	p value	MOD (95%CI)		Avatar	Conventional	p value	MOD (95%CI)
No Distraction	7 (6-8)	4 (4-6)	0.004	2 (0.7-3)	No Distraction	58 (50-70)	55 (40-60),	0.93	0.3 (-7-8)
Distraction	6 (5-7)	3 (2-4)	0.001	3 (1-4)	Distraction	75 (51-88)	75 (65-86)	0.007	9 (3-15)
p Value	0.014	0.010			p Value	<0.001	0.002		
MoD (95%CI)	1 (0.2-2)	2 (0.4-3)			MoD (95%CI)	24 (19-30)	13 (6-20)		

Electronic Supplementary Material

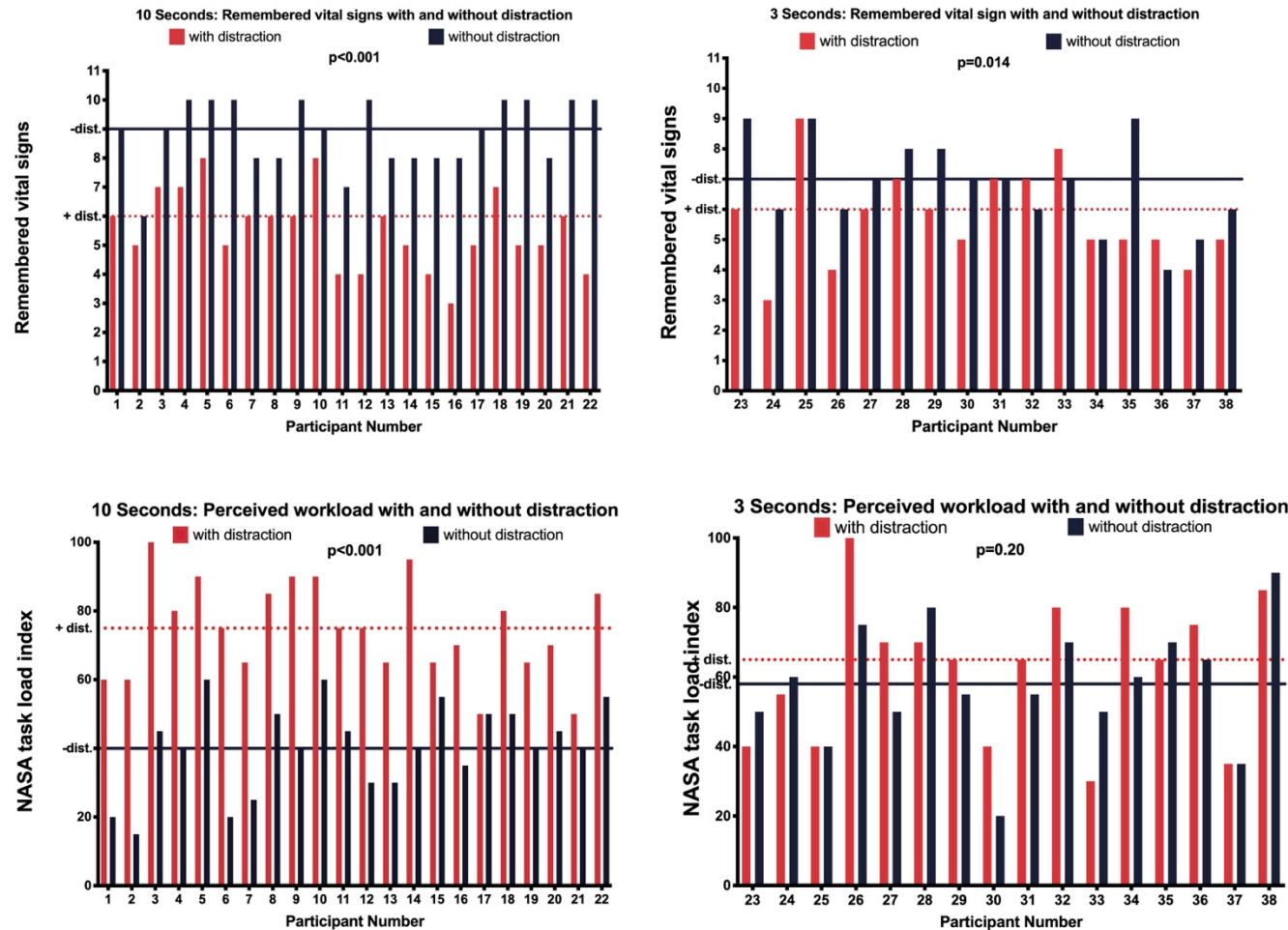
Effects of a standardized distraction on caregivers' perceptive performance with avatar-based and conventional patient monitoring: A multicenter comparative study.

Supplementary Figures 1-3

Supplementary Figure 1 Comparison of the participants' perceptive performance and perceived workload with the two monitoring technologies without distraction. Participants 1 to 8 and 31 to 38 were recruited at University Hospital Zurich and participants 9 to 30 were recruited at the Cantonal Hospital, Winterthur. The lines and the dotted lines represent the medians.



Supplementary Figure 2 Comparison of the participants' perceptive performance and perceived workload with and without distraction with avatar-based monitoring. Participants 1 to 8 and 31 to 38 were recruited at University Hospital Zurich and participants 9 to 30 were recruited at Cantonal Hospital Winterthur. The lines and the dotted lines represent the medians.



Supplementary Figure 3 Comparison of the participants' perceptive performance and perceived workload with and without distraction with conventional patient monitoring. Participants 1 to 8 and 31 to 38 were recruited at University Hospital Zurich and participants 9 to 30 were recruited at the Cantonal Hospital, Winterthur. The lines and the dotted lines represent the medians.

