Perceived Risk-Utility Tradeoffs of Medical Technology: A Visual Mapping

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Abstract:

The social acceptance of medical technology is crucial for the sustainability and effectiveness of healthcare systems, particularly in the context of demographic changes. Unlike most studies that focus on individual technologies, we measure the public perception across a range of medical technologies in a comprehensive study. We conducted an online survey with 193 participants from Germany and Bulgaria to assess perceived risk, utility, and overall attitudes (valence) toward 20 distinct medical technologies. This article presents a visual mapping of these technologies and investigates the individual and technology-related factors shaping these evaluations. Our findings suggest that perceived utility is the strongest predictor of overall attitude toward medical technology ($\beta = 0.886$), with perceived risk playing a significant, albeit much smaller, role ($\beta = -0.133$). Together, these factors explain a substantial portion of the variance in overall attitudes ($R^2 = .959$). Additionally, we found that individual differences, such as prior care experience and trust in physicians, significantly influence these perceptions. The article concludes with recommendations for effectively communicating the benefits and risks of medical technologies to the public, thereby enhancing their social acceptance and integration into healthcare systems.

Keywords: medical technology, risk perception, technology acceptance, user diversity, social acceptance

1. Introduction

The continued development of medical technologies is crucial to the viability of the healthcare sector in an aging society that leads to an increase in age-related diseases and associated health problems (European Commission, 2023; Börsch-Supan et al., 2015; Pickard, 2015). Diseases, such as cardiovascular disease, diabetes, and cancer continue to rise, and new and evolving infectious diseases, as the recent COVID-19 pandemic (Msemburi et al., 2022), threaten the healthcare systems around the world (World Health Organization, 2024; Deering, 2023).

To face this challenge, the development and implementation of medical technologies is crucial to improving health care and the quality of life of people. Medical technologies have many advantages: They enable better diagnoses, more effective treatments, and improved health monitoring (Cicirelli et al., 2021; Ahmed et al., 2020) and support personalized medicine (Goetz & Schork, 2018). Also, medical technologies can improve efficiency and sustainability by using less resources and reducing costs (Snoswell et al., 2020) and they improve coordination within the healthcare system, resulting in more seamless care (Mamlin & Tierney, 2016). Given their potential, it is essential that medical technologies continue to evolve to meet the continuously changing needs of the healthcare system and promote health and well-being of individuals and the society (Briganti & Le Moine, 2020; Pontillo, 2023).

The assessment of medical technology requires integration of many perspectives, such as the medical applicability, economic viability, and legal compliance. However, integrating social acceptance is equally crucial in medical technology assessment because widespread adoption and effective implementation depend on public trust, cultural alignment, and societal readiness. The patient perspective addresses issues such as accessibility, ease of use, and confidence in the technology (Or & Karsh, 2009). It is essential that patients feel comfortable and confident using new medical devices or applications, as this can influence their willingness to actively participate in their own healthcare. In addition, insights from the patient and the medical professionals' perspective can help break down barriers and facilitate the integration of new technologies into the healthcare system (Glenwright et al., 2023; Borges do Nascimento et al., 2023). Considering the patient's perspective is therefore an important step towards the successful introduction and use of medical technologies in the healthcare system.

Previous research in this field has predominantly focused on investigating the acceptance and evaluation of single technologies (see, for example, Peek et al., 2014 meta-study on many individual technologies) revealing that the perception of technology-specific benefits, barriers, and risks are relevant factors for the acceptance of medical and assistive technologies. Hence, there are many different studies on the perception of medical technology and the risk-utility tradeoffs focusing on individual technologies. However, we are not aware of any study that assesses the perception of different medical technologies in a joint study to facilitate a direct comparison.

Therefore, the current study provides a comprehensive comparison of a broad range of medical technologies in a joint study – focusing on perceived utility and risk as well as valence as a proxy for measuring acceptance. Our methodological approach focuses on quantitative analyses by means of conducting an online questionnaire using the micro-scenario-approach to realize a comparison of a broad range of technologies in one study. The paper's structure is as follows: first, the methodological approach of this study is introduced highlighting the innovative character of the applied micro-scenario-approach. Further, the results are described and discussed in the context of previous research in the field.

2. Methods

2.1. Empirical Approach

Instead of examining individual medical technologies, we assessed a set of 20 different technologies in a single comprehensive survey. We used the micro-scenario approach, where participants evaluate many different medical technologies presented with a short description on few outcome variables each (Brauner 2024). This approach offers two different perspectives on the assessments: First, for each outcome variable, the average evaluations of each participant across the technologies can be interpreted as an individual disposition, as it is a reflexive measurement of a latent construct through repeated measurements. Using this perspective, one can study, for example, the influence of age, gender, or care experience on these dispositions. Second, for each outcome variable, the average evaluation for each technology across the participants can be interpreted as an assessment of the technology. Using this perspective, one can compare the different technologies, identify outliers, and analyze relationships in the technology evaluations.

Through multiple workshops with researchers in the field of acceptance of medical technology, we compiled a set of 20 medical technologies (see Table 4). When making this selection, we excluded specialized or rare topics and include topics that have certain prominence that participants can evaluate. Further, we included medical technologies that are inversive and non-inversive, as well as digital and analog and ensured that the selection is not systematically biased (to avoid spurious findings owing to Berkson's paradox).

As dependent variables for the evaluations we asked for the perceived risk and perceived utility of the respective technology, as well as the participant's overall attitude or valence towards it (Kim 2007). Participants evaluated each variable on a single 6-point semantic differential (*risky–harmless*, *useless–useful*, *negative–positive*).

As explanatory user factors, we asked for the participants demographics, health, and care experience. For the demographics, we asked for the participant' gender (male, female, diverse, no answer), age in years, and the country the participants identify with most. For health- and care-related information (answer options: yes/no), we asked the participants if they suffer from a chronic illness. On an optional basis, the participants could indicate the type of illness they are suffering from. In addition, the participants answered if they depend on assistance and care in their everyday life. For quantifying private care experience, the participants indicated whether they have already cared for a person in need of care close to them. For the assessment of professional care experience, the participants answered the statement "*My job involves caring for people"*.

For measuring the experience with medical technology, we selected the four most common electrical consumer devices (blood pressure monitor, insulin pump, smartwatch, health apps). Lastly, we measured different individual attitudes of the participants on 6-point Likert scales using each 4–5 items, i.e., trust in physicians, self-efficacy in interacting with technology, need for privacy, and the participants' general risk perception. Figure 1 illustrates the design of the survey.

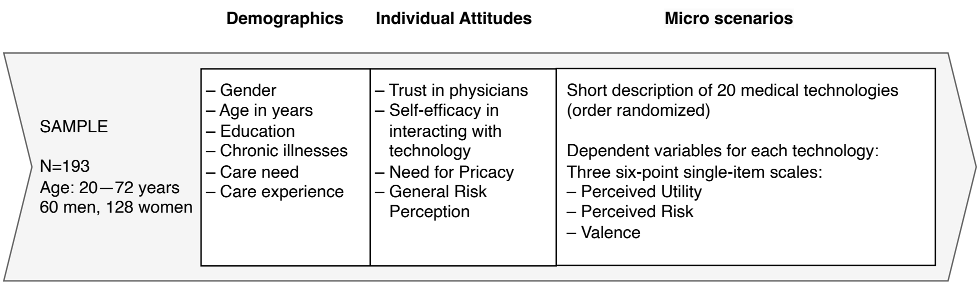

Fig. 1: Illustration of the survey with demographics, individual attitudes and the 20 micro-scenarios. Source: Own illustration.

2.2. Data Acquisition, Filtering, and Analysis

We used an online survey in Qualtrics to collect responses. To mitigate bias, we randomized the order of topics presented to participants. However, the order of the three target items was consistent for test efficiency. Utilizing convenience sampling, we distributed the survey via personal (e.g., personal email) and social networks (e.g., Facebook, LinkedIn). No incentives were provided, and participants were informed that their participation was voluntary, with the option to withdraw at any time (informed consent). Due to the researchers' social networks, the questionnaire was available in English, Bulgarian, and German. Depending on the measurement quality, we analyzed the data with non-parametrical and parametrical methods (Pearson's r and Kendell's τ correlations, multiple linear regressions). Following the conventions in the social sciences, we set the level of statistical significance to $\alpha = .05$. We cleaned the sample for speeders (less than 40% of the median survey duration of 14.4 min.) and only included participants from Germany and Bulgaria, as all other countries had less than 10 participants.

2.3. Sample Description

After cleaning the sample consisted of 193 participants in the age ranged between 20 and 72 years with a median age of 44 years (SD=13.6). 31.1% of the participants (n=60) identified themselves as male, 68.4% as female (n=132), and one participant did not answer this question (0.5%). N=142 (71.5%) participants were from Bulgaria and 51 (26.4%) participants came from Germany. Gender and age were not correlated in this sample (τ=.033, p=.535), however country was associated with both age ($\tau = .384$, $p \leq .001$) and gender ($\tau = .159$. $p = .028$). The sample was educated with as the majority of 75.6% (n=146) indicated to have a university degree and 3.1% (n=6) a doctoral degree, while only 21.2% (n=41) reported lower educational degrees (e.g., university entrance degree, secondary school certificates). Asked for health characteristics, a quarter of the participants (25.4%, n=49) reported suffering from a chronic illness, and mentioned examples referred to typical age-related illnesses, such as diabetes and high blood pressure. In line with this, a minority of the sample indicated to depend on care (12.2%, n=23). Beyond that, the participants were asked for their previous experiences in healthcare. Here, a proportion of 43.1% (n=81) reported to have already cared for a person in need of care close to them. Asked for professional experience, a minority of 12.8% (n=24) confirmed that their job deals with caring for people.

3. Results

The average perceived risk across all participants and all technologies is -44.4% (SD $=$ 56.4%), the average utility is $+65.0\%$ (SD $= 48.4\%$) and the average overall valence of $+62.4\%$ (SD $= 49.0\%$). Consequently, on average, the set of medical technologies in the study is perceived as rather safe and useful, and the participants have a positive overall attitude towards these. Figure 2 visualizes these findings.

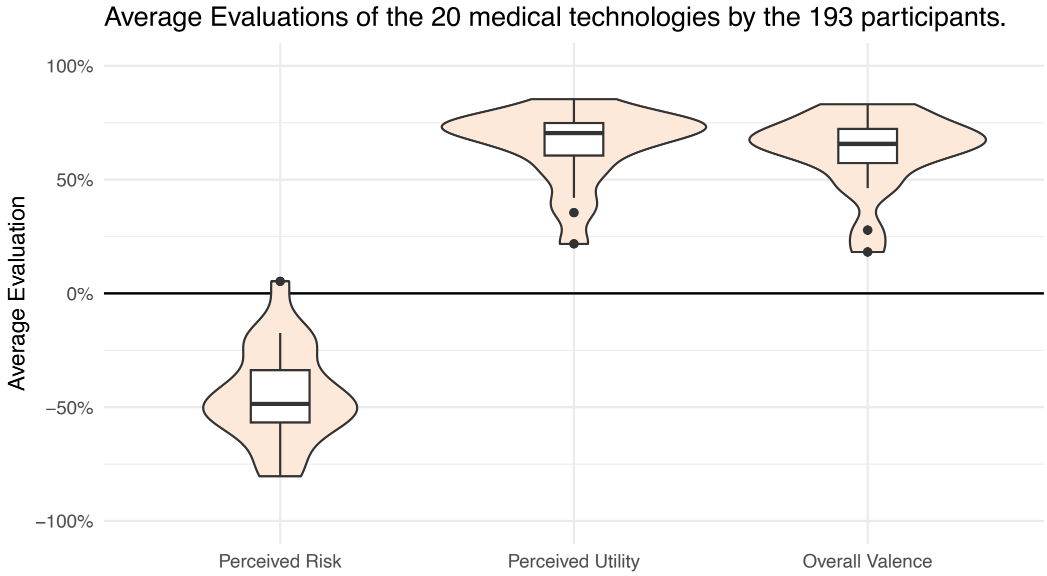

Fig. 1: Illustration how the 20 different medical technologies are assessed in terms of perceived risk, utility, and valence by the 193 participants. On average, the technologies are seen as safe, useful, and positive. The boxplot shows median, 25th/75th percentile and the yellow shape shows the frequency distribution of the evaluations for each dimension.

The medical technologies perceived as least risky were the analog blood pressure monitor (−80.3%), the home emergency call button (−77.2%), and the plaster cast (−69.0%). The technologies with the highest perceived risk were the X-ray (−19.1%), robotic surgery (−17.5%), and mRNA vaccines (+5.3%). With a positive risk score, only the last was perceived as slightly risky.

On perceived utility, the analog blood pressure monitor (+78.1%), the home emergency button (+82.8%), and magnetic resonance imaging (MRT) (+85.4%) were rated as most useful. Whereas preventive healthcare apps (+42.0%), nursing robots (+35.5%), and mRNA vaccines (+23.8%) were perceived as less useful, although still on the positive side of the scale.

Regarding the perceived valence a similar pattern emerged: The analog blood pressure monitor (+80.2), the home emergence button (+81.9%), and magnetic resonance imaging (+83.1%) were evaluated as the most positive medical technologies, whereas preventive healthcare apps (+46.2%), nursing robots (+27.8%), and mRNA vaccines (+18.2%) received the lowest, but still positive evaluations. Table 4 in the Appendix lists the assessment of every technology.

We now use the perceived risk and utility scores of each technology as coordinates and place the technologies on a map that can be interpreted in many ways (Brauner 2024): First, the distribution of the topics in regard to the studied dependent variables can be analyzed, e.g., how breadth or narrow is the distribution of technologies. Second, the map can be scanned for outliers. Third, the bivariate relationships can be interpreted, e.g., how strong is the relationship between risk and utility. Fig. 3 shows that most technologies lay in the upper left quadrant of the map with technologies with higher utility and lower risk. Only mRNA vaccines are in the quadrant of the higher risk and higher utility medical technologies.

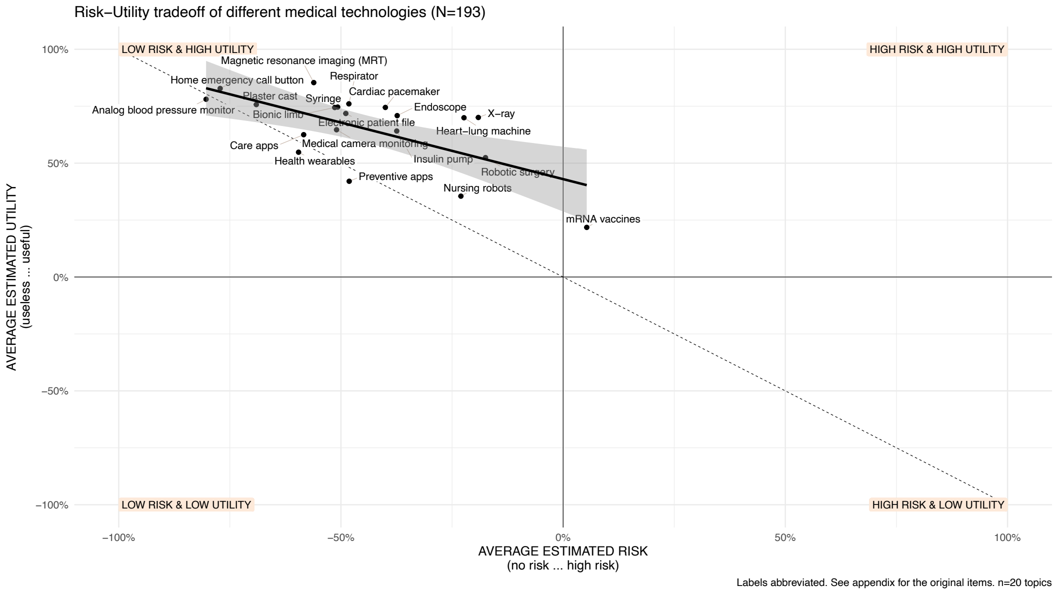

Fig. 2: Illustration of perceptions of different medical technologies in terms of risk and utility and the resulting regression line. Most medical technologies are seen as rather useful and rather safe and risk is associated with utility. The thin grey diagonal illustrates a balance between perceived risk and perceived benefits.

Overall, the assessment dimensions perceived risk, utility and overall valence are strongly correlated. There is a significant and strong negative correlation between Risk and Utility ($r = -.647, p = .002$) and risk and overall valence ($r = -.729, p = .001$). The correlation between utility and overall valence is significant, strong and positive ($r = .973, p < .001$). To disentangle the correlations, we calculated a multiple linear regression with risk and utility as independent and overall valence as dependent variable. The results of the regression yield a significant model with the two predictors risk and utility explaining 96.5% of the variance of overall valence ($R^2_{adj} = .959, F(2,17) = 224.2, p < .001$). The influence of risk on overall valence ($\beta_{\text{Risk}} = -0.133, p < .001$) is much smaller than the influence of usefulness ($\beta_{\text{Utility}} = 0.886, p < .001$). Following expectations, higher risk has a negative influence of overall valence, while higher benefits have a positive influence. Table 1 details the regression model.

Predictor	B	SE	β	T	p
(Intercept)	0.012	0.032	—	-0.381	$.708$
Risk	-0.134^{*}	0.048	0.133	-2.789	$.013^{*}$
Utility	$+0.886^{**}$	0.062	0.886	14.190	$< .001$

Tab. 1: Significant model of the multiple linear regression with Overall Valence as dependent variable and the average risk and utility scores of the 20 medical technologies as independent variables ($R^2_{adj} = .959$).

3.1. Influence of User Diversity

First, we analyzed if individual characteristics of the participants (demographics and attitudes) influence the evaluation of medical technology, i.e., the perception of risk, utility, and valence across all investigated technologies (see Table 2). The results revealed that the demographic characteristics of the participants—age, gender, and educational level—did not correlate with the evaluations of risk, utility, and valence (n.s.). Focusing on health- and care-related characteristics, the participants' health status was not significantly associated with the evaluation of medical technology (n.s.). In contrast, the care-related characteristics care need, i.e., "*being dependent on care*" (utility: $r = .166$, $p < .05$; valence: $r = .188$, $p < .05$), and private care experience, i.e., "having already cared for family member in need of care" utility: $r = .166$, $p < .05$; valence: $r = .211$, $p < .05$), were both weakly related with the evaluations of utility and valence. In contrast, professional care experience did not have any effect on the evaluation of medical technologies (n.s.). From the attitudes investigated, neither the self-efficacy in interacting with technology (n.s.) nor the participants' need for privacy (n.s.) was significantly correlated with the evaluation of medical technology. In line with this, also the participants' general risk perception and behavior (n.s.) did not reveal significant relationships with the evaluations of risk, utility, and valence. In contrast, trust in physicians based on previous experiences represented the own attitudinal variable which was significantly correlated with all three dimensions of evaluating medical technology: perceived risk ($r = -.186$, $p < .05$), perceived utility ($r = .193$, $p < .01$), and valence ($r = .194$, $p < .01$).

Predictor	Risk	Utility	Valence
Age	$-.030$	$-.062$	$.031$
Gender	$.130$	$-.008$	$-.030$
Education	$.039$	$.078$	$.092$
Health Status	$-.024$	$.084$	$.001$
Care Need	$\mathbf{-.101}$	$\mathbf{.166^{*}}$	$\mathbf{.188^{*}}$
Private Care Experience	$\mathbf{-.138}$	$\mathbf{.166^{*}}$	$\mathbf{.211^{**}}$

Prof. Care Experience	$.014$	$.082$	$.080$
Self-Efficacy Technology	$-.094$	$.116$	$.092$
Need for Privacy	$.110$	$-.060$	$-.064$
General Risk Perception	$-.023$	$-.041$	$.044$
Trust in Physicians	$\mathbf{-.186^*}$	$\mathbf{.193^{**}}$	$\mathbf{.194^{**}}$

Tab. 2: Correlations between user diversity factors and risk, utility, and valence (* = p<.05, **= p<.01).

To investigate the influence of the three significant user diversity factors on the participants' evaluation of the valence in medical technology, we calculated a multiple-linear regression with overall valence as dependent and care need, private care experience as well as trust in physicians as independent variables. Table 3 presents the significant model. Overall, the three independent variables explained 9.9% of the variance of the overall valence ($R^2 = .099$, $F(3{,}174) = 6.34, p < .001$) and were confirmed as relevant predictors of the overall valence.

Predictor	**B**	**SE**	$\boldsymbol{\beta}$	**T**	$\boldsymbol{p}$
Care Need	$.133$	$.064$	$.480$	2.090	$.038^*$
Private Care Experience	$.096$	$.041$	$.347$	2.339	$.020^*$
Trust in Physicians	$.050$	$.021$	$.170$	2.345	$.020^*$

Tab. 3: Significant model of the linear regression with Overall Valence as dependent variable and the user diversity factors (care need, private care experience, and trust in physicians) as independent variables.

4. Discussion

In this study, we asked participants of different ages, gender, and nationalities about their attitudes towards different medical technologies. In contrast to many other studies (e.g., Peek et al. 2014), we did not focus on a detailed evaluation of a single technology but rather let them evaluate a broad set of medical technologies, ranging from old and established to recent innovations. The survey provides two distinct perspectives. First, how individuals perceive medical technology in general in terms of risk, utility, and overall valence and how these measures relate to the other user factors (as a reflexive measurement of an individual difference). Second, how medical technologies are evaluated in terms of risk, utility, and valence and how different technologies relate to each other.

For the first perspective, this study corroborates that care experience influences the evaluation of the benefits and the acceptance of medical technologies (Jaschinski & Allouch, 2019). Results further suggest that trust in physicians represents a key factor in the risk-utility-perception as well as the acceptance of medical technologies.

For the second perspective, the results indicate that the set of queried medical technologies, on average, are seen as rather safe. The overall valence of medical technologies is explained by the utility attributed by the participants and to a much lesser extend by the perceived risk of using it. Beyond prior research that identified the perception of benefits and risks for the acceptance of medical assistive technology (Peek et al., 2014), our approach enabled the quantification of the relationships between utility, risk, and acceptance for a broad variety of different medical technologies.

Our analyses revealed significant relationships between individuals' care needs, their previous experiences in care, as well as trust in physicians, and the perceived valence of using medical technologies. This is relevant as care needs and prior experiences shape users' expectations and comfort with medical tools, influencing their willingness to adopt and trust these innovations. Furthermore, trust in physicians is important in determining how individuals perceive and accept technological interventions, as trusted sources can mitigate concerns and foster positive engagement. Understanding these relationships ensures that medical technologies are not only effective but also accessible, acceptable, and beneficial to a diverse range of users, thereby increasing adoption rates and enhancing patient outcomes in the healthcare system. These findings emphasize the necessity of incorporating individual differences in the design of technology and communication strategies. By addressing these individual characteristics, it is possible to better align future users' needs and requirements with the technologies they utilize.

Focusing on communication strategies related to medical technology, discussions in the media are often framed by the perceived risks. Our study, however, suggests that people rather build on the perceived benefits for forming their overall assessment in terms of the overall valence. While transparent communication on both the risks and benefits of medical technology is important. Our results suggest that focusing on communicating the benefits is the greater lever for the perceived valence and thus the acceptance of medical technology than mitigating the perceived risks.

This article analyzed the technology-related risk-utility tradeoffs and how individual factors, such as care experience, influence perceptions of risks, benefits, and overall valence. While the assessment of medical technology requires more than just social perspectives, low social acceptance can lead to reduced adoption or increased fear and resistance. Therefore, integrating social acceptance and the findings from this study alongside medical, economic, ethical, and legal considerations is crucial for ensuring the successful implementation and effectiveness of medical technology in real-world applications.

5. Limitations and Future Research

This study has its limitations. First, the presented study complements research on the detailed evaluation of a single medical technologies by analyzing many using the micro scenario approach. Hence, the assessments are based on an affective evaluation of the technologies and not on a deliberate weighting of the benefits and barriers. Our approach cannot explain the reasons for the evaluations, which would be subject to further studies. Second, the sample is biased and the findings are not easily generalizable. Nevertheless, the findings show high level of face validity and show systematic effects, which manifest, for example, in the high degree of explained variance in the risk-utility trade-offs. Hence, the results can inform researchers and policymakers about the risk-utility trade-offs on the one hand and the relative positioning of medical technology on the other. Further, the study can serve as a basis for a population-representative evaluation of various medical technologies across Europe and its different healthcare systems.

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Competing interests

The authors declare no competing interests.

Research data

Brauner, Philipp; Offermann, Julia (2024): Survey, data, and analysis notebook available as open data: https://osf.io/shvg7/ (link for reviewers https://osf.io/shvg7/?view_only=4258cf8fea5c4550b2600707f7a684ae)

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Appendix

Medical Technologies	Mean Risk (SD)	Mean Utility (SD)	Mean Valence (SD)
Plaster cast	-69.0% (SD=40.6%)	75.7% (SD=36.4%)	73.1% (SD=37.5%)
X-ray	-19.1% (SD=54.4%)	70.1% (SD=41.5%)	60.9% (SD=45.7%)
Endoscope	-37.3% (SD=54.6%)	70.9% (SD=40.5%)	68.3% (SD=38.3%)
Analog blood pressure monitor	-80.3% (SD=37.4%)	78.1% (SD=42.2%)	80.2% (SD=35.8%)
Respirator	-48.2% (SD=52.1%)	76.0% (SD=38.9%)	74.3% (SD=41.7%)
Magnetic resonance imaging (MRT)	-56.1% (SD=49.0%)	85.4% (SD=31.0%)	83.1% (SD=30.8%)
Cardiac pacemaker	-40.0% (SD=51.2%)	74.5% (SD=36.8%)	71.8% (SD=36.6%)
Health wearables	-59.5% (SD=48.9%)	54.8% (SD=52.2%)	56.7% (SD=49.5%)
Care apps	-58.4% (SD=49.2%)	62.5% (SD=44.9%)	64.5% (SD=44.0%)
Preventive apps	-48.1% (SD=51.4%)	42.0% (SD=54.9%)	46.2% (SD=49.9%)

Nursing robots	-23.0% (SD=59.9%)	35.5% (SD=56.7%)	27.8% (SD=61.3%)
Robotic surgery	-17.5% (SD=61.6%)	52.4% (SD=49.9%)	47.6% (SD=54.3%)
Electronic patient file	-48.9% (SD=57.9%)	71.8% (SD=49.2%)	65.2% (SD=48.7%)
Home emergency call button	-77.2% (SD=39.6%)	82.8% (SD=36.7%)	81.9% (SD=37.9%)
Insulin pump	-37.4% (SD=54.1%)	64.1% (SD=47.2%)	65.8% (SD=45.5%)
Medical camera monitor-ing	-51.0% (SD=53.7%)	64.7% (SD=47.1%)	57.5% (SD=51.3%)
mRNA vaccines	5.3% (SD=67.0%)	21.8% (SD=71.4%)	18.2% (SD=70.9%)
Bionic limb	-51.4% (SD=50.0%)	74.4% (SD=41.7%)	72.0% (SD=41.8%)
Syringe	-50.7% (SD=47.4%)	74.6% (SD=36.5%)	65.6% (SD=44.5%)
Heart-lung machine	-22.3% (SD=62.8%)	69.9% (SD=42.8%)	67.1% (SD=43.2%)
Overall Mean (SD)	**-44.5% (SD=52.1%)**	**65.1% (SD=44.9%)**	62.4% (SD=45.5%)

Tab. 4: Assessment of the different medical technologies by the participants in regard to perceived risk, utility, and overall valence.