

Table 5. Spearman correlations between results on motivation for health management, mobile device proficiency, and motivational design techniques.

motivational design technique <i>name</i>	intrinsic ρ [95%CI]	extrinsic ρ [95%CI]	amotivation ρ [95%CI]	mobile device proficiency ρ [95%CI]
INFORMATION	0.367 [0.08, 0.6]	0.248 [-0.05, 0.51]	-0.179 [-0.45, 0.12]	-0.108 [-0.39, 0.19]
micro-tailoring	0.363 [0.08, 0.59]	0.217 [-0.08, 0.48]	-0.411 [-0.63, -0.13]	-0.207 [-0.47, 0.09]
health education	0.286 [-0.01, 0.53]	0.14 [-0.16, 0.42]	0.001 [-0.29, 0.29]	0.01 [-0.28, 0.3]
fear appeal	0.159 [-0.14, 0.43]	0.234 [-0.06, 0.49]	-0.008 [-0.3, 0.29]	-0.039 [-0.33, 0.26]
macro-tailoring	0.37 [0.09, 0.6]	0.209 [-0.09, 0.47]	-0.051 [-0.34, 0.25]	-0.175 [-0.45, 0.12]
simulation	0.148 [-0.15, 0.42]	0.233 [-0.07, 0.49]	-0.067 [-0.35, 0.23]	-0.028 [-0.32, 0.27]
TRUSTWORTHINESS & LIKING	0.312 [0.02, 0.55]	0.169 [-0.13, 0.44]	-0.343 [-0.58, -0.05]	0.271 [-0.02, 0.52]
surface credibility	-0.097 [-0.38, 0.2]	-0.008 [-0.3, 0.29]	-0.219 [-0.48, 0.08]	0.133 [-0.17, 0.41]
personalisation	-0.087 [-0.37, 0.21]	-0.078 [-0.36, 0.22]	-0.221 [-0.48, 0.08]	0.337 [0.05, 0.57]
expertise	0.541 [0.29, 0.72]	0.322 [0.03, 0.56]	-0.214 [-0.48, 0.09]	0.1 [-0.2, 0.38]
verifiability	0.424 [0.15, 0.64]	0.251 [-0.05, 0.51]	-0.241 [-0.5, 0.06]	0.122 [-0.18, 0.4]
AWARENESS & PERSONAL INSIGHTS	0.343 [0.06, 0.58]	0.025 [-0.27, 0.32]	-0.194 [-0.46, 0.11]	0.409 [0.13, 0.63]
progress	0.091 [-0.21, 0.37]	0.199 [-0.1, 0.47]	-0.239 [-0.5, 0.06]	0.193 [-0.11, 0.46]
logging	0.18 [-0.12, 0.45]	-0.012 [-0.3, 0.28]	-0.037 [-0.33, 0.26]	0.341 [0.05, 0.58]
self-monitoring	0.388 [0.11, 0.61]	0.1 [-0.2, 0.38]	-0.053 [-0.34, 0.24]	0.223 [-0.08, 0.48]
tracking	0.333 [0.04, 0.57]	-0.086 [-0.37, 0.21]	-0.178 [-0.45, 0.12]	0.402 [0.12, 0.62]
self-goal setting	0.217 [-0.08, 0.48]	-0.091 [-0.37, 0.21]	-0.213 [-0.48, 0.09]	0.209 [-0.09, 0.47]
automatic goal setting	0.194 [-0.11, 0.46]	0.106 [-0.19, 0.39]	-0.108 [-0.39, 0.19]	0.256 [-0.04, 0.51]
ABILITY	0.404 [0.13, 0.62]	0.117 [-0.18, 0.4]	-0.21 [-0.47, 0.09]	0.131 [-0.17, 0.41]
rehearsal	0.163 [-0.14, 0.44]	-0.138 [-0.41, 0.16]	-0.282 [-0.53, 0.01]	0.217 [-0.08, 0.48]
tunneling	0.243 [-0.05, 0.5]	0.249 [-0.05, 0.51]	-0.016 [-0.31, 0.28]	-0.051 [-0.34, 0.25]
reduction	0.274 [-0.02, 0.53]	0.03 [-0.27, 0.32]	-0.14 [-0.42, 0.16]	0.186 [-0.11, 0.46]
reminders	0.477 [0.21, 0.68]	0.186 [-0.11, 0.45]	-0.043 [-0.33, 0.25]	0.112 [-0.19, 0.39]
instructions	0.285 [-0.01, 0.53]	0.0 [-0.29, 0.29]	-0.154 [-0.43, 0.15]	0.121 [-0.18, 0.4]
guiding avatar	0.318 [0.03, 0.56]	0.06 [-0.24, 0.35]	-0.225 [-0.49, 0.07]	-0.022 [-0.31, 0.27]
implementation intention	0.044 [-0.25, 0.33]	0.182 [-0.12, 0.45]	-0.067 [-0.35, 0.23]	0.217 [-0.08, 0.48]
SOCIAL INTERACTIONS	0.258 [-0.04, 0.51]	0.129 [-0.17, 0.41]	0.037 [-0.26, 0.33]	-0.227 [-0.49, 0.07]
social support	-0.013 [-0.31, 0.28]	0.352 [0.07, 0.58]	0.187 [-0.11, 0.46]	-0.413 [-0.63, -0.14]
cooperation	0.244 [-0.05, 0.5]	0.146 [-0.15, 0.42]	-0.193 [-0.46, 0.11]	-0.117 [-0.4, 0.18]
social identification	0.21 [-0.09, 0.47]	-0.03 [-0.32, 0.27]	-0.094 [-0.38, 0.2]	-0.091 [-0.37, 0.21]
social comparison	0.031 [-0.26, 0.32]	0.064 [-0.23, 0.35]	-0.012 [-0.3, 0.28]	-0.074 [-0.36, 0.22]
social competition	0.224 [-0.07, 0.49]	0.019 [-0.28, 0.31]	0.096 [-0.2, 0.38]	-0.035 [-0.33, 0.26]
INCENTIVISATION	0.079 [-0.22, 0.36]	0.248 [-0.05, 0.5]	0.298 [0.0, 0.54]	-0.165 [-0.44, 0.14]
praise	0.025 [-0.27, 0.32]	0.114 [-0.19, 0.39]	0.127 [-0.17, 0.41]	0.212 [-0.09, 0.48]
monetary rewards	-0.122 [-0.4, 0.18]	0.07 [-0.23, 0.36]	0.248 [-0.05, 0.5]	0.064 [-0.23, 0.35]
complimentary rewards	-0.107 [-0.39, 0.19]	0.202 [-0.1, 0.47]	0.295 [0.0, 0.54]	-0.313 [-0.56, -0.02]
recognition	-0.043 [-0.33, 0.25]	0.04 [-0.26, 0.33]	0.028 [-0.27, 0.32]	-0.101 [-0.38, 0.2]
game	0.167 [-0.13, 0.44]	0.164 [-0.14, 0.44]	0.043 [-0.25, 0.33]	-0.278 [-0.53, 0.02]

Information. On average, MDT within this category correlate moderate ($\pm.3$) with intrinsic motivation ($\rho = .367$). In total, it comprises three correlations between specific MDT and the different levels of motivation that score at least moderate; more specifically macro-tailoring ($\rho = .370$) and micro-tailoring ($\rho = .363$) have a moderate correlation with intrinsic motivation, and additionally, micro-tailoring also has a large, negative ($\rho = -.411$) correlation with amotivation.

Trustworthiness & Liking. On average, MDT within this category correlate moderate ($\pm.3$) with both intrinsic motivation ($\rho = .312$) and, although negative, with amotivation ($\rho = -.343$). In total, it comprises three correlations between MDT and the different

levels of motivation that score at least moderately. Both *expertise* ($\rho = .541$) and *verifiability* ($\rho = .424$) have respectively a strong and large correlation with intrinsic motivation. Additionally, expertise also shows a moderate correlation with extrinsic motivation ($\rho = .322$).

Awareness & Personal Insights. On average, MDT within this category correlate moderate ($\pm.3$) with intrinsic motivation ($\rho = .343$). In total, it comprises two correlations between MDT and the different levels of motivation that score at least moderately. In particular, self-monitoring ($\rho = .388$) and tracking ($\rho = .333$) correlate moderately with intrinsic motivation.

Ability. On average, MDT within this category correlate moderate ($\pm .3$) with intrinsic motivation ($\rho = .404$). In total, it comprises two MDT and the different levels of motivation that score at least moderately. In particular, reminders ($\rho = .477$) and guiding avatars ($\rho = .318$) correlate respectively large and moderately with intrinsic motivation.

Social Interactions. On average, MDT within this category correlate weak ($\leq .3$) with the different types of motivation. In total, it comprises only one correlation that scores at least moderately, i.e., between social support and extrinsic motivation ($\rho = .352$).

Incentivisation. On average, MDT within this category correlate moderately ($\pm .3$) with amotivation ($\rho = .298$). In total, it comprises no moderate to strong correlations between MDT and any of the different levels of motivation.

5.6. RQ3. Does mobile device proficiency mediate the preference towards motivational design techniques?

Similar to the previous research question, a Spearman (ρ) correlation⁵ was performed between MDP and preferences for MDT. Results are displayed in table 5. Afterwards, participants' scores for MDP were categorised as low ($MDP \leq 19.2$) or high ($MDP > 19.2$) and analysed based on violin plots that were split on the level of MDP. Below results for each category will be discussed.

Information. No moderate correlations can be found in this category. However, most items tend to have a weak and negative correlation with MDP, suggesting that the more experienced with mobile devices, the less interested in these techniques.

Figure 2 shows mainly positively skewed distributions, indicating that accessing relevant information sources seems to be important for both participants with high and low MDP.

Trustworthiness & Liking. On average, MDT within this category correlate weakly ($\leq .3$) with MDP ($\rho = .271$). In total, it comprises one moderate correlation between personalisation ($\rho = .337$) and MDP, which was thus more preferred by those with a higher MDP.

Figure 3 indicates that overall, participants all had a positive score for these techniques. However, it can also be noted that participants with low MDP often scored either neutral or positive towards the MDT.

Awareness & Personal Insights. On average, MDT within this category correlate moderately ($\pm .3$) with MDP ($\rho = .409$). In total, it comprises three moderate correlations with MDP; tracking ($\rho = .402$), logging ($\rho = .341$), and automatic goal setting ($\rho = .256$) would then be preferred.

According to figure 4, it is clear that participants with a high MDP were mostly positive towards the different MDT. Participants with a low MDP again often scored neutral, but also showed some preferences for tracking, self-goal setting, and progress.

Ability. On average, MDT within this category do not seem to correlate with MDP ($\rho = .131$); none of the specific MDT showed a correlation with MDP representing at least a medium effect.

When inspecting the results in figure 5, participants with a high MDP showed more positive skewed distributions, while participants with a low MDP often scored more neutral.

Social Interactions. On average, MDT within this category showed a negative but weak ($\leq .3$) correlation with MDP ($\rho = -.227$). In total, it comprises only one moderate and negative correlation with MDP, social support ($\rho = -.413$). However, for this category, all underlying MDT seem to correlate negative, although weak. This could indicate that participants with a high MDP would dislike having these MDT implemented.

When investigating figure 6, results of participants with a low MDP are again more distributed around zero, whereas the other participants show more widespread results. Social support and social comparison indicate a higher preference for participants without any experience than those with a high MDP.

Incentivisation. On average, MDT within this category showed a negative but weak ($\leq .3$) correlation with MDP ($\rho = -.165$). In total, it comprises only one moderate and negative correlation with MDP, complimentary rewards ($\rho = -.313$).

Figure 7 shows that results are more spread for participants with a high MDP than those with a low MDP. Participants with less experience again more often scored neutral to the different techniques, whereas participants with a high MDP showed, except for monetary rewards and praise, show rather negatively skewed distributions.

Influence of high versus low mobile device proficiency on preference towards motivational design techniques. A Mann-Whitney U test was conducted for every category to observe these differences between participants with high and low MDP. Awareness & personal insights did show a significant difference ($U = 310.0, p = .005$); participants with a high MDP (mean=1.81, SD=.719) tend to have a higher preference for these MDT than participants with a low MDP (mean=1.13, SD=.825). Also trustworthiness & liking showed a significant difference ($U = 303.5, p = .008$) between participants with a high MDP (mean=2.12, SD=.574) and those with a low MDP (mean=1.50, SD=.798). No significant differences were found for ability ($U = 250.5, p = .146$), information ($U = 183.5, p = .736$), incentivisation ($U =$

125.5, $p = .983$), and social interactions ($U = 142.0, p = .953$).

From the violin plots, it was also observed that participants with a low MDP more often scored neutral compared to those with a high MDP. In order to verify this observation, a joint plot was generated. Figure 8 visualises a joint plot between the individual scores on all MDT, and the according MDP scores. Across the x- or y-axis, the distribution for respectively MDT scores and MDP are visualised. The hexagons show all answers, whereas a darker colour indicates more similar responses. On the one hand, this figure shows that scores for MDT have a positively skewed distribution. On the other hand, the dark hexagons at the bottom left quadrant indicate that participants with no or very low MDP tend to score most often neutral or positive. Moreover, a Chi-Square test was performed to investigate whether there was, in general over all MDT, a difference between MDP (low or high) and scoring (neutral or other). A statistically significant association was found between MDP and scoring $\chi^2(1) = 36.8, p = 0$.

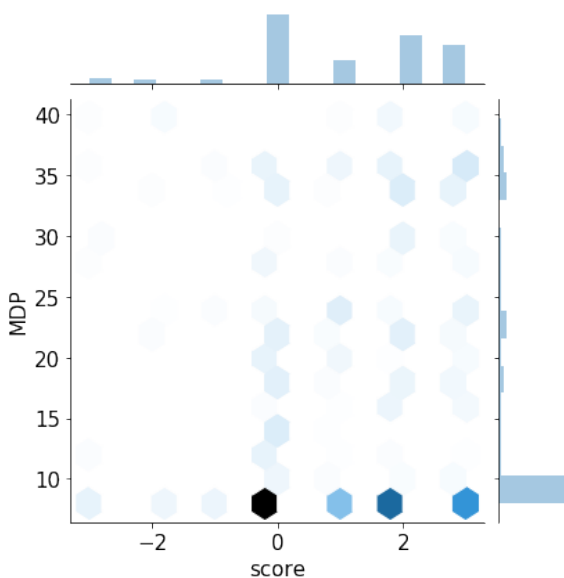


Figure 8. Joint plot between individual scores on all motivational design techniques and the score on the mobile device proficiency questionnaires.

6. Discussion

In this study, we interviewed 45 older adults, with an average age of 84, regarding their preferences for 32 different MDT, embedded in interactive systems to self-manage health. Besides, we polled for levels of intrinsic, extrinsic and amotivation for self-managing health, their technological proficiency and investigated

associations with preferences for MDT. In the paragraphs below, we first reflect on the different research questions and relate them to earlier work. We end with formulating implications for the design of SMHS for older adults and suggest avenues for future research.

6.1. Revisiting the search questions

RQ1. What are the preferences of older adults towards different motivational design techniques? Concerning the first research question, we found that, on average, older adults welcomed MDT; 28 out of 32 MDT received a positive score. However, the scores also show large standard deviations, reflecting the heterogeneity among participants. This observation is further unpacked in section 6.2.

Based on our findings, MDT that provide information on managing health, tailored to the older adult, were most preferred. Next, older adults also welcomed MDT that increase overall trustworthiness and liking of the application. MDT that increase awareness and provide them with the ability to managing their health were also valued. Somewhat less favoured were techniques that focus on social comparisons or competitions with friends and families. Least liked were techniques that favour virtual incentives, sharing (successes) through social media or being rewarded with mini-games.

These exploratory findings are in line with findings by Geuens et al. [55] who also found social support and incentivisation to score least among MDT, whereas techniques related to information, ability, awareness and trustworthiness were much liked. Altmeyer et al. [28] also found virtual rewards such as badges and points as least preferred, but did find social techniques scoring well. These findings are also not entirely in line with the results from van Velsen et al. [30]. Moreover, in our study, overall appreciation towards the MDT scored higher compared to van Velsen et al. [30].

RQ2. Does motivation for self-management of health mediate the preference towards motivational design techniques? Results suggest that older adults are motivated to self-manage their health. Participants scored positive on both intrinsic and extrinsic motivation, and negative on amotivation. Compared to other studies [30, 32], it is remarkable that participants in our study scored equally high on extrinsic levels of motivation as intrinsic levels of motivation.

Based on our study's findings, intrinsic motivation is at least moderately correlated with four out of six categories, i.e., information, trustworthiness & liking, awareness & personal insight, and ability. Intrinsic motivation is correlated with providing health information in general, and in particular, with providing personalised and tailored health information. Intrinsic motivation is also related to increasing

trustworthiness & liking, and in particular by unveiling experts and highlighting credible sources. Intrinsic motivation is also correlated with increasing awareness & personal insights, in particular through self-monitoring and tracking. Finally, intrinsic motivation is correlated with supporting ability and, in particular, by providing reminders and offering a guiding avatar. Extrinsic motivation, instead, only has a moderate correlation with showing experts behind the application and allowing friends and family to send encouraging messages. Amotivation had a moderate positive correlation with incentivisation, in general, and correlated moderately and negative with offering personalised information and reinforcing trustworthiness & liking.

These correlations are in line with literature on intrinsic versus extrinsic motivation and health-related behaviour [62, 72]. As suggested by [84], participants who are intrinsically motivated will value MDT supporting their specific health-related actions and increasing insights. Participants who are more extrinsically motivated value encouragement and backup from experts. Finally, those that are amotivated overall do not favour MDT. However, unlike van Velsen et al. [30], we found not all MDT had a positive relationship with intrinsic or extrinsic motivation.

RQ3. Does mobile device proficiency mediate the preference towards motivational design techniques? When assessing MDP, the majority (n=32) of the participants had little to no experience; only 13 participants had used either a smartphone or tablet. We found that MDP correlated to personalisation, as well as being able to log and track. MDP was negatively correlated to receiving encouraging messages through an SMHS (social support) or the offering of virtual rewards and badges (complimentary rewards). However, further analysis showed that those scoring low in MDP more often choose to score an MDT as neutral; this observation is discussed in the limitations.

6.2. Motivational design techniques – one size does not fit all

While scores of MDT were overall positive, caution is needed; the scores also showed large standard deviations, reflecting the heterogeneity among participants in how MDT were perceived. Concerning gamification, van Roy et al. [85] have detailed how even one badge can be assigned nine different functionalisations, i.e., meanings, from status markers to contingent rewards, depending on user characteristics and situational context [85]. These different functionalisations impact experience, motivation and behaviour. In this study, participants spanned a wide range of age, gender, living arrangements, education, and *life history*. Recognising a life span perspective, as noted by Vines et al. [86],

citing Bond et al. [87]: “Rather than growing more alike as we age, we become more unique.” [87]. This heterogeneity of the older population group has already been confirmed in previous studies, as well as its impact on attitudes towards health-related technologies, e.g., [11, 12, 88, 89]. Hence, it needs to be acknowledged that the same MDT can hold radically different meanings for different older adults, or even the same older adult, over time.

Through the interviews, we understood that some participants perceived themselves as ‘too old’ for using these techniques. These older adults often still scored preferences for MDT neutral, yet hinted that these MDT were not for them anymore, i.e., “I will do it my way” as a woman aged 91 often stated. Besides, some participants also mentioned that they were just not interested in these MDT. As earlier work indicated, perceived usefulness is one of the main barriers for technology adoption in older adults [12, 90]. Taken this into account, it will remain difficult to persuade participants who are amotivated to self-manage health to use an SMHS in the first place [30, 32].

Participants interested in using an SMHS and favoured MDT, emphasised the importance of managing their health *for themselves* and the need to recognise that every older adult is unique; in their self-management trajectory. Moreover, participants noted this trajectory is unpredictable, even for them. They had to “take each day as it comes”. This may explain why participants, while overall liking MDT related to ability and awareness, liked least those MDT such as automatic goal setting or implementation intentions. From older adults’ explanations, it was understood that such MDT were oftentimes perceived as undermining their autonomy. This may also explain why participants disliked social competition or comparisons, as every person’s situation is unique. Such MDT could set expectations that they might not be able to meet and should, therefore, be treated carefully. This is in line with earlier work from Geuens et al. [55] who stated that in applications for chronic disease management, MDT that target social interaction or provide incentives actually lower motivation of patients to use the application, as “every patient hurts in their own way” [55]. In our study as well, it was found that participants highly valued their autonomy, one of the primary drivers for intrinsic motivation [91], and needed MDT to respect and reflect this uniqueness.

6.3. Implications for design

For designers of SMHS, this study yields insights into which and how MDT are worth implementing in SMHS for older adults. Based on the results, (1) *providing information on how to manage a healthy lifestyle* was valued by most participants. Especially

if it could be (2) *tailored information, but with respect for the individual*. Besides, users should be able to inspect and (3) *verify the designers' expertise or content within the application*. Designers should acknowledge the heterogeneity among older adults, and MDT should (4) *keep the life span perspective of the user in mind*. When implementing MDT, it is therefore important to (5) *ensure that the techniques are not intrusive*. Techniques (6) *targeting stringent and normative frames should be avoided*, e.g., taking 10.000 steps a day. Consequently, (7) *the user should always have the autonomy to choose their own goals*. Participants need to follow their own pace and see how they feel, thus listening to their bodies. For this reason, (8) *selecting goals should also be made flexible and adaptive from day to day*.

Receiving social support was valued by the participants. However, they should again be (9) *given sufficient autonomy to choose how their (care) network interacts with the application*, e.g., receiving motivational messages was found pleasant. However, they did not want to burden their loved ones with results available in the SMHS; this was rather for physicians or caregivers. Social interactions that arise from (10) *comparisons or competition should be avoided*; every older adult is unique in their management of health and well-being. Besides support, older adults also (11) *valued instructions, or a guiding avatar to help them through the application*. Also, (12) *being able to personalise the application* was valued by older adults. However, they are (13) *not eager for mini-games* to be part in SMHS, and at least would want to be able to skip these. Finally, (14) *advertisements should be avoided at all costs*, as this was overall, the most important MDT.

7. Limitations and future work

We observed that an interviewer was needed to assist in filling out the questionnaires. However, the presence of this interviewer may have introduced bias in the answers of older adults.

Additionally, in this study, we wanted to investigate how to design an SMHS for older adults. Therefore, we tested which design techniques participants would welcome and which not. In this regard, it was clearly mentioned that participants could score 'neutral' (score=0) if inclusion of the MDT would neither make the application better nor worse. When analysing the results, we observed that participants often gave 'neutral' scores, most often by those who scored low on MDP. Therefore, these zero-scores may reflect a limited understanding of the MDT rather than an actual neutral scoring. In order to further scrutinise attitudes, in-depth interviews are needed.

Finally, although the MDP questionnaire was selected with the greatest care as a questionnaire specifically

geared towards mobile device proficiency and validated with older adults, still, for the sample of oldest older adults in our sample, we likely hit a floor effect, resulting in zero-inflated data. We recommend future research to investigate technological proficiency further, perhaps also focusing on anxieties towards novel technologies [92–94].

8. Conclusion

In this study, a user evaluation with 45 participants was conducted to understand which MDT older adults would appreciate in SMHS. The user evaluation was conducted based on questionnaires polling for the personal motivation of self-managing their health, a questionnaire polling for their experience in mobile device proficiency, and a questionnaire polling for their preference towards 32 different MDT. During the questionnaires, participants were encouraged to support their answers. This exploratory research study investigated (1) preferences of older adults towards different MDT, (2) motivation for self-management of health mediating the preference towards MDT, and (3) MDP mediating the preference towards different MDT in SMHS. Especially techniques related to information, trustworthiness & liking, and awareness & personal insights portray a bright future. However, older adults are a heterogeneous group and thus call for being able to tailor the techniques to the wishes of the individual. Moreover, these MDT are no panacea; participants who are not motivated to self-manage a healthy lifestyle would probably also not benefit from any of these techniques. It was also noteworthy that most participants had little MDP and, in addition, also scored more 'neutral' towards MDT. After answering the different research questions and relating these to earlier work, implications for design were presented to help future designers of SMHS in making informed decisions on which MDT they would (not) want to include in their SMHS. However, this study's limitations necessitate further research, e.g., a hands-on adoption study, to let older adults gain salient experiences and make sure that they can make an informed decision. These further research studies are essential in order to validate, clarify, and extend our findings.

Acknowledgement

We would like to thank Triamant [79] for their cooperation, as well as all participants who agreed on conducting this research study.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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