Title

Factors influencing participants' engagement with an interactive text-message intervention to improve sun protection behaviors: "SunText" Randomized Controlled Trial

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Transparency statements: The study protocol and the analysis plan were prospectively registered with the Australian and New Zealand Clinical Trials Registry (registration number: ACTRN12618001299291). De-identified data from this study will be made available (as allowable according to institutional IRB standards) by emailing the corresponding author. There is no analytic code associated with this study.

ABSTRACT

Background: There is growing evidence suggesting that text-message based interventions are effective to promote sun protection behaviors. However, it is still unclear how engagement and adherence with the intervention messages can be optimized through intervention design.

Purpose: This study evaluated the effect of different combinations of personalized and two-way interactive messages on participant engagement with a theory-based skin cancer prevention intervention.

Methods: In the SunText study conducted in February-July 2019 in Queensland, Australia participants 18-40 years were randomized to four different text message schedules using a Latin square design. This study analyzed if the order and intensity in which the schedules were received were associated with participants' level of engagement, and if this differed by demographic factors.

Results: Out of the 389 participants enrolled in the study, 375 completed the intervention period and remained for analysis. The overall intervention engagement rate was 71% and decreased from the beginning to the end of the study (82.2%-61.4%). The group starting with personalized, but not interactive messaging showed the lowest engagement rate. The intervention involving interactive messages 3 times a week for 4 weeks achieved the highest engagement rate. The intervention with increasing frequency (personalized and interactive 3 times a week for 2 weeks; then daily for 2 weeks) had lower engagement than intervention with constant or decreasing frequency.

Conclusions: Engagement with two-way interactive messages was high across all intervention groups. Results suggest enhanced engagement with constant or decreasing message frequency compared to increasing frequency.

Keywords: skin cancer; prevention; health promotion; mHealth; text-delivered intervention; engagement

INTRODUCTION

Skin cancer, including keratinocyte cancers (KCs) and melanoma, causes substantial burden for health and economic systems worldwide. In the USA, approximately 5 million people are treated for skin cancer every year, with an estimated annual cost of nearly $8 billion [1]. For melanoma, 106,110 new cases and 7,180 deaths are estimated to occur in 2021 [2]. Australia has one of the highest rates of melanoma in the world [3], where it is the most common cancer among young Australians aged 15 to 44 years [4]. Two out of three Australians will develop at least one skin cancer in their lifetime.

Australia has successfully implemented skin cancer prevention campaigns which achieved reductions in melanoma incidence among younger generations [5] and were successful in creating skin cancer awareness and adoption of safe sun behaviors [6, 7]. However, there has been no major government-funded campaign over the last decade [6]. Recent decreases in sun protection practices and increases in sunburns in Australian youth [8, 9] stress the importance of again increasing awareness. Carefully designed communication strategies are necessary, especially using digital technologies, delivered via the world-wide-web or mobile phones, which are now the main communication and information avenues used by youth [10].

A widely used mobile health (mHealth) communication technology is text messaging. Growing evidence suggests text message-delivered interventions are effective in improving health prevention behaviors, such as diabetes management, smoking cessation, and weight loss [11-13], as well as sun protection behaviors [14]. Advantages of text messaging-delivered interventions include ability for two-way interactive dialogue, tailored content, and responsiveness to participants at a low cost and high reach. It also facilitates the delivery of messages when they may have the greatest impact, such as on days with high UV index or times commonly spent outside, which may reinforce sun protection.

Non-engagement with intervention features may compromise their effectiveness [15, 16]. The importance of measuring user engagement with components of the intervention such as interaction with the text messages has been called upon [16]. If participants do not interact with features of the interventions, such as some texts being ignored, exposure to the intervention will be limited and less likely to translate into sustained behavior change. A recent meta-analysis suggested that interventions with high (d=0.27, 95% confidence interval [CI]: 0.10-0.44), moderate (d=0.26, 95% CI: 0.16-0.35) and decreasing messaging frequency (d=0.32, 95% CI: 0.19-0.45) and of at least 6 months in length (d=0.46, 95% CI: 0.32-0.60) were the most effective for behavior change [12]. However, studies to determine the best intervention design to improve engagement with text messaging-delivered interventions aimed to change sun protection behaviors are lacking. Furthermore, despite demonstrated effectiveness of behavior change interventions guided by theory [17] and growing theoretical grounding of mHealth interventions, further studies that apply health behavior theory are needed [18-20].

This study aimed to determine whether different types of interactive two-way text messaging of a theory-based health promoting intervention resulted in differences in participants' engagement with the intervention, and whether participants' demographic, behavioral and skin cancer characteristics were associated with engagement. We also assessed participants' knowledge and attitudes towards skin cancer prevention and early detection reflected in their responses to the text messages.

METHODS

Intervention design

Briefly, a Latin square crossover design [21] was used to investigate the intervention order effect and account for its presence. Participants were enrolled into the study and completed the eligibility survey in December 2018 to early February 2019. Participants were randomly assigned into one of four groups (Groups 1, 2, 3, 4) and based on that group, rotated

through four intervention types (A, B, C, D) in different order over 5 months (February 2019-July 2019) (Table 1). Each intervention A-D lasted 4 weeks, followed by a one week wash out period in between them. Intervention A was personalized messages 3 times a week for 4 weeks; Intervention B was interactive messages 3 times a week for 4 weeks; Intervention C was personalized and interactive daily messages for first 2 weeks, then 3 times a week messaging for another 2 weeks (decreasing frequency); and Intervention D was personalized and interactive 3 times a week for 2 weeks at start, then daily messaging for the last 2 weeks (increasing frequency). Since intervention A was personalized but not interactive, data for intervention A were excluded from further analysis. Data were analyzed in 2020.

This trial was prospectively registered with the Australian and New Zealand Clinical Trials Registry [removed for masked review]. Detailed methods of the trial, including sample size calculations and behavior change were reported elsewhere [22].

Participants

Participants were men and women 18-40 years living in Queensland, Australia. To be included, participants had to understand sufficient English; cognitive ability to consent; access to a smart phone; and presence of at least two skin cancer risk factors (light hair color, skin that rarely or never tans, skin that burns easily, many moles, family/personal history of skin cancer). There were no exclusion criteria related to gender, race or ethnicity in the selection of participants.

Participants were recruited via the population-based Australian Medicare system, sponsored Facebook social media posts by the university and television news. Participants were asked to visit a study-specific website to provide informed consent and complete the eligibility screening and baseline survey.

Participants were eligible to enter a prize drawn to win sun safety products after the completion of each study survey (baseline, washout periods and end of intervention). There were no specific incentives for engagement with the text messages.

Interactive two-way text messages

In total participants received 64 text messages. Interactive text messages required participants to action a response back to the received text message, or to click on a website link. Of these, 38 were interactive two-way messages that required participants to action back a response. We define engagement as the extent to which people respond to these interactive two-way messages.

Messages were also personalized to participant's demographic and phenotypic characteristics (such as gender, age and skin type) and attitudes towards sun protection. Due to the personalization, not all participants received the same two-way text messages. For example, males (n=66/375) and females (n=309/375) and people ≤30 years (n=237/375) or >30 years (n=138/375) received different gender and age-based personalized messages. Males received a total of 32 two-way messages and females 33.

The Capability, Opportunity and Motivation to Behavior (COM-B) model guided message development [23]. Messages were tested in consumer focus groups. Messages addressed the following components of the COM-B model: 'Capability', individual's psychological and physical ability (*16 messages*); 'Motivation', automatic and reflective processes (*4 messages)*; 'Opportunity', physical and social environment *(5 messages);* and 'Behavior', sun protection behaviors *(13 messages)*.

Text messages were delivered using *Propelo* behavioral coaching software [24]. Messages were automatically sent by the platform in the morning, to encourage sun protective behaviors from the start of the day. Pre-defined responses such as 'yes'; 'no'; triggered automated responses. A research assistant manually responded to text messages if participants responded outside of the pre-defined options within 24 hours. The software

automatically saved and archived all messaging data, including messages sent and responded to by participants. Participants could withdraw at any time by sending a “stop” message or contacting the research team.

Outcomes

The primary outcome was participants’ engagement rates, defined as the number of messages responded to by a participant divided by the number of messages received during an intervention period. A secondary outcome was the proportion of responses received for each interactive two-way message.

Statistical analysis

Descriptive analysis

Descriptive statistics of number of participants and their average engagement rate were calculated by intervention period, group, intervention type, socio-demographic and risk factor characteristics.

Model building

Although the original engagement rate outcomes were discrete ordinal values, their skewed distribution was not suitable for linear regression. Thus, we categorized the engagement rate into three levels representing low (responded to less than 70% of the messages, “<70%”); medium (at least 70% but less than 100%, “70%-<100%”); and high engagement rates (responded to 100% of the messages, “100%”). Since the data did not satisfy the proportional odds assumption for ordinal logistic regression [25], multinomial logistic regression models [26] were used to explore the effects of intervention period, group, intervention type, socio-demographic and risk factor characteristics on the engagement rate. To account for the repeated measurement of engagement rate for each individual, data were considered as clustered by individual when building the models.

The multinominal logistic regression output is expressed in terms of relative risk ratios (RRR), comparing the probability. If the RRR is 1 (or close to 1), it suggests no probability or little probability of having low, medium or high engagement rates. A RRR>1 suggests increased probability and a RRR<1 suggests reduced probability of having low, medium or high engagement rates.

Three multinomial logistic regression models were used, reflecting the three different combinations of pairs of period (P), group (G) and intervention type (I), along with the interaction between those pairs. This meant that model 1 included I, G and I*G, model 2 included P, G and P*G, and model 3 included I, G and I*G. Due to the Latin square design, once two of the P, G, and I were set, the third one was decided. Therefore, the three models represented the same associations from different perspectives.

All three models were adjusted for selected socio-demographic and skin cancer risk characteristics. The list of potential variables include age, gender, marital status, income, education, employment, skin, hair, and eye color, number of moles, freckles at the end of summer, skin tan, times of suntan within the past 12 months, sunburn during the past four weeks, and sun protection habits (SPH) index during the past four weeks [27]. The variables to be included in the model development process were initially chosen by a-priori known associations with the outcome measure. Since more parsimonious models can be preferred for clinical applications [28], a variable selection process was used to reduce the number of variables in each model. The model development process was carried out separately for each of the three models using a combination stepwise procedure [29]. This consisted of a backward stepwise regression procedure, with a likelihood ratio test used to drop the variable having the weakest association (with p-value>0.2) at each step. In addition, at each step, variables previously removed from each model were tested using the likelihood ratio test to gauge their eligibility to be re-included into the model.

Sensitivity analysis

Given that the choice of cut points had the potential to influence the reported results based on categorized variables [30], post-hoc sensitivity analyses were carried out to test if different cut points significantly influenced the pattern of engagement rate over time and intervention. Separate logistic regression models were used with binary cut points to assess how the effects of period and intervention type varied. The original ordinal engagement rate outcome was converted to four binary variables using four cut points (≤50% and >50%; ≤70% and >70%; ≤85% and >85%; <100% and =100%).

Proportion of responses to interactive two-way messages

In this analysis we explored participants' responses to two-way messages to understand participants' skin cancer prevention knowledge, attitudes and behaviors. We reported the proportion of responses (e.g. 'yes', 'no') and the proportion of no response for each message.

RESULTS

Overall, 427 individuals registered and the intervention was commenced by 389 participants (Figure S1). Of these, 375 participants completed the intervention period (did not actively withdraw) and remained for analysis. The attrition rate immediately after the intervention was 3.6% (Group 1 n=94, Group 2 n=93, Group 3 n=92, Group 4 n=96).

Participant demographic characteristics

Participant characteristics are reported in Table 2. Participants were predominantly female (82.4%, n=309/375), highly educated with a university degree (68%, n=255/375) and had income of ≤$51,599 (52.8%, n=198/375). Most participants had very fair/fair skin type (76.5%, n=287/375).

Primary outcome - Participants' engagement rates

Observed engagement rate

The overall engagement rate across the whole intervention period was 71.0% (95% CI: 66.4%-75.6%) (Table 2). The average engagement rate decreased over time, from 82.2% (95% CI: 77.7%-86.7%) in period 1, to 61.4% (95% CI: 55.7%-67.1%) in period 4. The overall engagement rates for interventions B (interactive messages 3 times a week for 4 weeks), C (personalized and interactive daily for first 2 weeks; then 3 times a week for another 2 weeks) and D (personalized and interactive 3 times a week for 2 weeks; then daily for last 2 weeks) were 69.5% (95% CI: 68.0%-71.0%), 73.0% (95% CI: 68.5%-77.5%), and 70.3% (95% CI: 65.7%-74.9%), respectively. Participants from group 1 (starting with intervention A, personalized 3 times a week for 4 weeks) had the lowest overall engagement rate (58.9%; 95% CI: 49.0%-68.8%) and group 2 (starting with intervention B) had the highest engagement rate (79.1%; 95% CI: 70.8%-87.4%).

Trends in engagement rate by period

Within the same group, the probability that the participants responded to 100% of the text messages was generally lower later in the study (periods 3 and 4) (Table 3, Figure S2), with all RRRs less than 1 (Table S1). For example, for participants in group 1, the probability that the participants responded to 100% of the text messages decreased by 72% (RRR=0.28, 95% CI: 0.14-0.59, $p<0.01$) in period 4 compared to period 2 (Table S1).

For each intervention, the probability of having a 100% engagement rates was generally higher in period 1 and decreased over time (Table 3, Figure S3). For example, for intervention B, the probability that participants responded to 100% of the text messages decreased from 56.1% (95% CI: 46.4%-65.7%) in period 1 to 34.7% (95% CI: 25.3%-44.1%) in period 4 (Table 3).

Trends in engagement rate by intervention

Participants receiving intervention B (interactive messages 3 times a week for 4 weeks) had higher probability of having a 100% engagement rate, while those receiving intervention D (personalized and interactive 3 times a week for 2 weeks; then daily for last 2 week) had lower probabilities of having a 100% engagement rate (Table 3, Figure S3 and S4). For example, in period 1, 56.1% (95% CI: 46.4%-65.7%) of intervention B participants had 100% engagement, compared to 25.6% for intervention D (95% CI: 16.9%-34.2%) (Table 3).

Trends in engagement rate by group

Group 2, which started with intervention B, had the highest probability of having a 100% engagement rate, while group 1, which started with intervention A, had the lowest probability (Table 3 and S3, Figure S2). For example, for intervention B, the probability that the participants responded to 100% of text messages was 5.12 (95% CI: 2.35-11.1, $p<0.01$) times higher for Group 2 than Group 1 (Table S3).

Trends by participants' demographics

The probability that participants responded to 100% of text messages was lower for those with a higher income, with all RRRs <1 (Table S1-S3). There was some evidence that participants with a SPH index ≥3 over the previous four weeks tended to have higher probability of responding to 100% of text messages (RRR=1.55, 95% CI: 0.96-2.50, $p=0.07$) than those with a SPH <3. There was no statistically significant evidence that other participants' demographics, such as age, gender and education, and behavioral and skin cancer characteristics, such as skin and hair color, number of moles and number of sunburns were associated with engagement rates.

Sensitivity analysis

Logistic regression models for the binary outcome variables with different cut points showed that the patterns of probabilities of having higher engagement rate over time were similar for

all the three interventions, regardless which cut points were chosen (Figure S5). These results suggest that the patterns observed from the models were robust.

Secondary outcome - Proportion of responses to interactive two-way messages

Table 4 presents the proportion of responses to each interactive two-way message. Overall, the proportion of participants who did not respond to the messages, varied from 17.87% (n=67/375) to 46.59% (n=41/88). Overall, the proportion of participants whose responses were outside the options provided (e.g. 'yes' or 'no'), such as "not sure", varied from 0.27%, (n=1/375) to 4.27% (16/375) per text message.

Sun protection and skin cancer early detection behaviors reflected in participant answers

The most correctly answered question by the respondents (80.5%; n=302/375) was that sunburns can occur on a cloudy day (Table 4). The least accurately understood statement was about skin cancer types, with only 23.7% (n=89/375) aware that there are three main types. A large proportion of female participants had not heard of photoaging (61.5%, n=190/309).

Regarding sun protection behaviors, 62.7% consider their experiences with sunscreen sticky and greasy (n=235/375). More than 50% of the participants had been sunburnt after using sunscreen (n=218/375) and often forgot to apply it (n=200/375). Just under half of participants responded they had not recently checked their sunscreen expiry date (n=182/375). Approximately 31% (n=116/375) reported they did not check their skin for skin cancer.

DISCUSSION

The widespread use of smartphones and the simplicity, cost-effectiveness and wide reach of text messaging make it a valuable delivery method for health promotion interventions. Acceptability of this intervention delivery was high in the present study. Almost all participants remained during the 5-month intervention period and while engagement with the

interactive messaging decreased over time, a high proportion of participants (82% to 61% depending on group) actively responded in the final period of the intervention. The intensity of the intervention contributed to engagement, with intervention B (involving the same number of text messages (3 times per week)) achieving the highest engagement rate, while intervention D (message frequency increasing from 3 times a week to daily) had the lowest engagement rate. These results suggest that careful consideration of the optimal frequency of messaging is important to achieve good engagement. We had hypothesized that increase in message frequency later in the intervention period may help participants to solidify newly formed sun protection habits. The results indicate that this strategy was not optimal for participants, who preferred the texts to be constant in frequency. Policy makers who want to decrease sunburn, and skin cancer rates, should be advised to invest in text messaging interventions, applying interactive and personalized messages with constant or decreasing message frequency to optimize participant engagement. In this study, participants were not given an option on timing/frequency of text messages. Future interventions may benefit from further insights by allowing flexibility of days and time of the day text messages are sent. The lower engagement observed at the end of the intervention may have been due to these texts being delivered in winter. Participants reported they found the text messages less useful in winter, which may have resulted in lower engagement [22]. Researchers should also evaluate the option of participants being able to change the frequency and time of the messages throughout the study in future research.

Loss of engagement can reduce the achievable intervention impact and create issues such as bias (if those who disengage are systematically different from those who do not), reduced data quality, and high rates of missing data [31]. This study demonstrated very low attrition rates when compared to other eHealth interventions which report attrition rates of up to 85% and low levels of engagement [32, 33]. While it is difficult to avoid some degree of attrition in longitudinal interventions and as in our SunText study, participant burden is likely to contribute [31]. The lower response rate in our study in later periods, which ran over 5

months, suggests that some level of respondent burden may have been present. This is consistent with previous digital health interventions which reported that engagement often drops after the first few weeks of study commencement [34, 35]. Interestingly, the group that started the intervention without interactive messaging (intervention A) consistency had the lowest engagement rate throughout the study period. This suggests participants may ignore subsequent messages if they do not rapidly engage with the intervention from the beginning.

Participants with higher income or lower sun protection habits were less likely to respond to the messages. This is in contrast to previous studies which have found that engagement with digital interventions is usually higher among participants with higher income and education [36]. Other factors that influence participant engagement include message content, for example messages that highlight the positive over the negative and benefit-oriented messages [37]. A previous review of digital intervention for weight management highlighted the importance of user-centered design process to increase engagement [38]. For this study, we conducted focus groups to obtain feedback with the proposed messages which may have contributed to the good engagement achieved.

Analysis of responses to the two-way interactive messages showed that participants were aware of the importance of sun protection practices; but this did not always translate into action. While most participants were aware of sun protection, such as the risk of sunburn on cloudy days, deficits in knowledge were also obvious, especially about the types of skin cancers. Previous work reported that social norms, media pressure, and a culture that encourages sun exposure strongly influence behaviors [39].

In regards to sunscreen practices, a large proportion of participants reported sunburn after using sunscreen, did not like the feel of sunscreen and consider it to be sticky and greasy, all of which may indicate the sunscreen was not applied correctly. Our team conducted a study on unintended sunburn after sunscreen application and found participants did not reapply often enough and overestimated the lengths of time they could be safely exposed to the sun

[40]. A New Zealand study found unintended sunburn was more likely among participants using sunscreen and with high knowledge scores [41].

Limitations

While largely automated, some of the incoming participant responses outside pre-defined options required the researchers to manually responding to text messages. This requires time commitment by the research staff, and may not be feasible for interventions with substantial sized populations [36]. This study focused on engagement levels in young people 18-40 years. Younger people tend to be more familiar with using technology, and their usage levels may be different to older or less technologically adept populations.

CONCLUSION

This study demonstrated very high levels of engagement with two-way text-messages in a skin cancer prevention intervention. The results suggest that engagement may be enhanced by initiating interventions with a maximal frequency of three times a week or by decreasing the frequency of messages over time. In contrast, increasing frequency of messages does not increase engagement. The results of this study add to the current knowledge on text-messaging intervention design and provide insights to sustain the effectiveness of mHealth interventions in skin cancer prevention specifically, and likely for other health behaviors as recently reviewed [12]. Policy makers should invest in text messaging interventions, applying interactive and personalized messages with constant or decreasing message frequency to optimize participant engagement. Further participant consultation and personalization of the frequency and timing messages are sent may lead to enhance engagement and this should be explored further in future research.

REFERENCES

1. Guy, G. P., Jr., Machlin, S. R., Ekwueme, D. U., & Yabroff, K. R. (2015). Prevalence and costs of skin cancer treatment in the U.S., 2002-2006 and 2007-2011. *Am J Prev Med, 48*(2), 183-187. doi:10.1016/j.amepre.2014.08.036

2. National Cancer Institute. Cancer stat facts: melanoma of the skin Retrieved from https://seer.cancer.gov/statfacts/html/melan.html

3. Australian Institute of Health and Welfare. (2016). Skin cancer in Australia. Retrieved from https://www.aihw.gov.au/getmedia/0368fb8b-10ef-4631-aa14-cb6d55043e4b/18197.pdf.aspx?inline=true

4. Australian Institute of Health and Welfare. (2018). Cancer in adolescents and young adults in Australia Retrieved from https://www.aihw.gov.au/getmedia/ed22109b-ab23-4273-8d23-7949a8922ea2/aihw-can-110.pdf.aspx?inline=true

5. Baade, P. D., Green, A. C., Smithers, B. M., & Aitken, J. F. (2011). Trends in melanoma incidence among children: possible influence of sun-protection programs. *Expert Rev Anticancer Ther, 11*(5), 661-664. doi:10.1586/era.11.28

6. Montague M, Borland R, & Sinclair C. (2001). Slip! Slop! Slap! and SunSmart, 1980-2000: skin cancer control and 20 years of population-based campaigning. *Health Educ Behav, 28*(3), 290-305. doi:10.1177/109019810102800304

7. Dobbinson, S. J., Volkov, A., & Wakefield, M. A. (2015). Continued impact of SunSmart advertising on youth and adults' behaviors. *Am J Prev Med, 49*(1), 20-28. doi:10.1016/j.amepre.2015.01.011

8. Volkov, A., Dobbinson, S., Wakefield, M., & Slevin, T. (2013). Seven-year trends in sun protection and sunburn among Australian adolescents and adults. *Aust N Z J Public Health, 37*(1), 63-69. doi:10.1111/1753-6405.12012

9. Koch, S., Pettigrew, S., Hollier, L. P., Slevin, T., Strickland, M., Minto, C., . . . Lin, C. (2016). Trends in Australian adolescents' sun-protection behaviours: implications for health campaigns. *Aust N Z J Public Health, 40*(5), 468-473. doi:10.1111/1753-6405.12561

10. Pew Research Center. (2019 Jun12). Mobile fact sheet. Retrieved from https://www.pewresearch.org/internet/fact-sheet/mobile/

11. Head, K. J., Noar, S. M., Iannarino, N. T., & Grant Harrington, N. (2013). Efficacy of text messaging-based interventions for health promotion: a meta-analysis. *Soc Sci Med, 97*, 41-48. doi:10.1016/j.socscimed.2013.08.003

12. Armanasco, A. A., Miller, Y. D., Fjeldsoe, B. S., & Marshall, A. L. (2017). Preventive health behavior change text message interventions: a meta-analysis. *Am J Prev Med, 52*(3), 391-402. doi:10.1016/j.amepre.2016.10.042

13. Orr, J. A., & King, R. J. (2015). Mobile phone SMS messages can enhance healthy behaviour: a meta-analysis of randomised controlled trials. *Health Psychol Rev, 9*(4), 397-416. doi:10.1080/17437199.2015.1022847

14. Finch, L., Janda, M., Loescher, L. J., & Hacker, E. (2016). Can skin cancer prevention be improved through mobile technology interventions? A systematic review. *Prev Med, 90*, 121-132. doi:10.1016/j.ypmed.2016.06.037

15. Perski, O., Blandford, A., West, R., & Michie, S. (2017). Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. *Transl Behav Med, 7*(2), 254-267. doi:10.1007/s13142-016-0453-1

16. Cole-Lewis, H., Ezeanochie, N., & Turgiss, J. (2019). Understanding health behavior technology engagement: pathway to measuring digital behavior change interventions. *JMIR Form Res, 3*(4), e14052. doi:10.2196/14052

17. Glanz, K., & Bishop, D. B. (2010). The role of behavioral science theory in development and implementation of public health interventions. *Annu Rev Public Health, 31*, 399-418. doi:10.1146/annurev.publhealth.012809.103604

18. Bull, S., & Ezeanochie, N. (2016). From Foucault to Freire through Facebook: toward an integrated theory of mHealth. *Health Educ Behav, 43*(4), 399-411. doi:10.1177/1090198115605310

19. Zaslavsky, O., Roopsawang, I., & Chen, A. T. (2020). Promoting behavioral change in mobile health interventions for older adults: a scoping review. *Res Gerontol Nurs, 13*(2), 102-116. doi:10.3928/19404921-20191031-01

20. Hoque, M. R., Rahman, M. S., Nipa, N. J., & Hasan, M. R. (2020). Mobile health interventions in developing countries: a systematic review. *Health Informatics J, 26*(4), 2792-2810. doi:10.1177/1460458220937102

21. Kempthorne, O. (1953). The design and analysis of experiments. *Phys Today, 6*(5), 18. doi:10.1063/1.3061232

22. [removed for masked review]

23. Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci, 6*, 42. doi:10.1186/1748-5908-6-42

24. [removed for masked review]

25. Kim, J.-H. (2003). Assessing practical significance of the proportional odds assumption. *Stat Probab Lett, 65*(3), 233-239. doi:10.1016/j.spl.2003.07.017

26. Hamilton, L. C., & Seyfrit, C. L. S. T. B., 1993. (1993). Interpreting multinomial logistic regression. *Stata Technical Bulletin, 13*, 24-28.

27. Glanz, K., Schoenfeld, E. R., & Steffen, A. (2010). A randomized trial of tailored skin cancer prevention messages for adults: project SCAPE. *Am J Public Health, 100*(4), 735-741. doi:10.2105/AJPH.2008.155705

28. Ambler, G., Brady, A. R., & Royston, P. (2002). Simplifying a prognostic model: a simulation study based on clinical data. *Stat Med, 21*(24), 3803-3822. doi:10.1002/sim.1422

29. Henderson, D. A., Denison, D. R. (1989). Stepwise regression in social and psychological research *Psychol Rep, 64*(1), 251–257. doi:10.2466/pr0.1989.64.1.251

30. Thabane, L., Mbuagbaw, L., Zhang, S., Samaan, Z., Marcucci, M., Ye, C., Thabane, M., Giangregorio, L., Dennis, B., Kosa, D., Debono, V. B., Dillenburg, R., Fruci, V., Bawor, M., Lee, J., Wells, G., & Goldsmith, C. H. (2013). A tutorial on sensitivity analyses in clinical trials: The what, why, when and how. *BMC Med Res Methodol, 13*(1), 92-92. doi:10.1186/1471-2288-13-92

31. Druce, K. L., Dixon, W. G., & McBeth, J. (2019). Maximizing engagement in mobile health studies: lessons learned and future directions. *Rheum Dis Clin North Am, 45*(2), 159-172. doi:10.1016/j.rdc.2019.01.004

32. Schubart, J. R., Stuckey, H. L., Ganeshamoorthy, A., & Sciamanna, C. N. (2011). Chronic health conditions and internet behavioral interventions: a review of factors to enhance user engagement. *Comput Inform Nurs, 29*(2), 81-92. doi:10.1097/NCN.0b013e3182065eed

33. Yeager, C. M., & Benight, C. C. (2018). If we build it, will they come? Issues of engagement with digital health interventions for trauma recovery. *Mhealth, 4*, 37. doi:10.21037/mhealth.2018.08.04

34. Bennett, G. G., & Glasgow, R. E. (2009). The delivery of public health interventions via the Internet: actualizing their potential. *Annu Rev Public Health, 30*, 273-292. doi:10.1146/annurev.publhealth.031308.100235

35. Conroy, D. E., Yang, C. H., Lanza, S. T., Smyth, J. M., & Lagoa, C. M. (2020). Temporal dynamics of treatment receipt in a text message intervention for physical activity: single-group, within-person trial. *JMIR Mhealth Uhealth, 8*(4), e14270. doi:10.2196/14270

36. Yardley, L., Spring, B. J., Riper, H., Morrison, L. G., Crane, D. H., Curtis, K., . . . Blandford, A. (2016). Understanding and promoting effective engagement with digital behavior change interventions. *Am J Prev Med, 51*(5), 833-842. doi:10.1016/j.amepre.2016.06.015

37. Thomas, K., Linderoth, C., Bendtsen, M., Bendtsen, P., & Mussener, U. (2016). Text message-based intervention targeting alcohol consumption among university students: findings from a formative development study. *JMIR Mhealth Uhealth, 4*(4), e119. doi:10.2196/mhealth.5863

38. Sharpe, E. E., Karasouli, E., & Meyer, C. (2017). Examining factors of engagement with digital interventions for weight management: rapid review. *JMIR Res Protoc, 6*(10), e205. doi:10.2196/resprot.6059

39. Mingoia, J., Hutchinson, A. D., Gleaves, D. H., Corsini, N., & Wilson, C. (2017). Use of social networking sites and associations with skin tone dissatisfaction, sun exposure, and sun protection in a sample of Australian adolescents. *Psychol Health, 32*(12), 1502-1517. doi:10.1080/08870446.2017.1347788

40. [removed for masked review]

41. McLeod, G. F. H., Reeder, A. I., Gray, A. R., & McGee, R. (2017). Unintended sunburn: a potential target for sun protection messages. *J Skin Cancer, 2017*, 6902942. doi:10.1155/2017/6902942

Table 1. Latin square crossover design

	Period 1 (4 weeks)	**Period 2 (4 weeks)**	**Period 3 (4 weeks)**	**Period 4 (4 weeks)**
Group 1	A	B	C	D
Group 2	B	C	D	A
Group 3	C	D	A	B
Group 4	D	A	B	C

Intervention A: Personalized messages 3 times a week for 4 weeks
Intervention B: Interactive messages 3 times a week for 4 weeks
Intervention C: Personalized and interactive daily for first 2 weeks; then 3 times a week for another 2 weeks (decreasing frequency)
Intervention D: Personalized and interactive 3 times a week for 2 weeks; then daily for last 2 weeks (increasing frequency)

Table 2. Number of participants and observed average engagement rate (ER in %) by periods

	Total		Period 1		Period 2		Period 3		Period 4	
	N	ER	N	ER	N	ER	N	ER	N	ER
Overall	**375**	**71.0 (66.4-75.6)**	**281**	**82.2 (77.7-86.7)**	**279**	**72.4 (67.2-77.6)**	**283**	**68.0 (62.6-73.4)**	**282**	**61.4 (55.7-67.1)**
Group										
Group 1	94	58.9 (49.0-68.8)	-	-	94	61.6 (51.8-71.4)	94	64.7 (55.0-74.4)	94	50.5 (40.4-60.6)
Group 2	93	79.1 (70.8-87.4)	93	83.1 (75.5-90.7)	93	78.4 (70.0-86.8)	93	75.8 (67.1-84.5)	-	-
Group 3	92	77.7 (69.2-86.2)	92	85.7 (78.5-92.9)	92	77.3 (68.7-85.9)	-	-	92	70.0 (60.6-79.4)
Group 4	96	68.4 (59.1-77.7)	96	77.9 (69.6-86.2)	-	-	96	63.7 (54.1-73.3)	96	63.8 (54.2-73.4)
Intervention										
Intervention B	375[1]	69.5 (68.0-71.0)	93	83.1 (75.5-90.7)	94	61.6 (51.8-71.4)	96	63.7 (54.1-73.3)	92	70.0 (60.6-79.4)
Intervention C	375	73.0 (68.5-77.5)	92	85.7 (78.5-92.9)	93	78.4 (70.0-86.8)	94	64.7 (55.0-74.4)	96	63.8 (54.2-73.4)
Intervention D	375	70.3 (65.7-74.9)	96	77.9 (69.6-86.2)	92	77.3 (68.7-85.9)	93	75.8 (67.1-84.5)	94	50.5 (40.4-60.6)
Age										
18-21	94	67.8 (58.4-77.2)	65	79.8 (70.0-89.6)	71	74.0 (63.8-84.2)	70	61.7 (50.3-73.1)	76	57.2 (46.1-68.3)
22-26	93	75.2 (66.4-84.0)	81	82.5 (74.2-90.8)	60	77.9 (67.4-88.4)	70	71.9 (61.4-82.4)	68	67.6 (56.5-78.7)
27-33	101	71.5 (62.7-80.3)	76	82 (73.4-90.6)	81	72.2 (62.4-82.0)	74	68.5 (57.9-79.1)	72	62.7 (51.5-73.9)
34-40	87	69.3 (59.6-79.0)	59	84.6 (75.4-93.8)	67	65.9 (54.5-77.3)	69	69.9 (59.1-80.7)	66	58.3 (46.4-70.2)
Gender										
Male	65	65.2 (53.6-76.8)	44	78.9 (66.8-91.0)	52	70.5 (58.1-82.9)	48	62.1 (48.4-75.8)	51	50.9 (37.2-64.6)
Female	309	72.1 (67.1-77.1)	236	82.8 (78.0-87.6)	226	72.7 (66.9-78.5)	234	69.1 (63.2-75.0)	231	63.7 (57.5-69.9)
Other	1	89.8 (30.5-100.0)	1	85.7 (17.1-100.0)	1	92.9 (42.6-100.0)	1	90.9 (34.5-100.0)	0	-
Marital status										
Married/partner	168	71.8 (65.0-78.6)	133	83.8 (77.5-90.1)	125	70.0 (62.0-78.0)	118	68.7 (60.3-77.1)	128	63.9 (55.6-72.2)
Others	207	70.3 (64.1-76.5)	148	80.7 (74.3-87.1)	154	74.3 (67.4-81.2)	165	67.5 (60.4-74.6)	154	59.3 (51.5-67.1)
Income										
≤$20,799	125	72.7 (64.9-80.5)	94	83.9 (76.5-91.3)	93	77.5 (69.0-86.0)	94	66.8 (57.3-76.3)	94	62.5 (52.7-72.3)
$20,800-$51,599	73	72.2 (61.9-82.5)	54	82.6 (72.5-92.7)	58	69.7 (57.9-81.5)	52	71.0 (58.7-83.3)	55	65.9 (53.4-78.4)
$52,000-$90,999	114	73.8 (65.7-81.9)	95	83.5 (76.0-91.0)	79	75.6 (66.1-85.1)	88	71.3 (61.8-80.8)	80	63.5 (53.0-74.0)
≥$91,000	36	63.3 (47.6-79.0)	24	83.1 (68.1-98.1)	26	58.5 (39.6-77.4)	26	61.9 (43.2-80.6)	32	53.6 (36.3-70.9)
Prefer not to answer	27	57.5 (38.9-76.1)	14	58.2 (32.4-84.0)	23	62.8 (43.0-82.6)	23	60.2 (40.2-80.2)	21	48.4 (27.0-69.8)
Education										
High school/trade/diploma	120	70.8 (62.7-78.9)	92	81.5 (73.6-89.4)	92	74.5 (65.6-83.4)	88	66.2 (56.3-76.1)	88	60.1 (49.9-70.3)
University	255	71.1 (65.5-76.7)	189	82.5 (77.1-87.9)	187	71.3 (64.8-77.8)	195	68.8 (62.3-75.3)	194	61.9 (55.1-68.7)
Employment										
Employed full time	149	69.7 (62.3-77.1)	113	81.7 (74.6-88.8)	108	69.9 (61.2-78.6)	112	67.0 (58.3-75.7)	114	60.1 (51.1-69.1)
Student	123	70.7 (62.7-78.7)	83	82.3 (74.1-90.5)	97	72.5 (63.6-81.4)	93	67.5 (58.0-77.0)	96	61.7 (52.0-71.4)
Other	103	73.2 (64.6-81.8)	85	82.6 (74.5-90.7)	74	75.7 (65.9-85.5)	78	70.0 (59.8-80.2)	72	62.9 (51.7-74.1)
Skin color										
Very fair	120	73.2 (65.3-81.1)	103	82.9 (75.6-90.2)	82	73.5 (63.9-83.1)	89	71.2 (61.8-80.6)	86	63.4 (53.2-73.6)
Fair	167	71.4 (64.5-78.3)	118	84.5 (78.0-91.0)	129	72.2 (64.5-79.9)	126	68.1 (60.0-76.2)	128	61.9 (53.5-70.3)
Medium to brown	88	67.1 (57.3-76.9)	60	76.5 (65.8-87.2)	68	71.4 (60.7-82.1)	68	63.7 (52.3-75.1)	68	57.8 (46.1-69.5)
Hair color										

Red/Auburn/Blonde	86	75.5 (66.4-84.6)	72	86.3 (78.4-94.2)	59	75.1 (64.1-86.1)	64	73.2 (62.3-84.1)	63	65.9 (54.2-77.6)
Light/mouse brown	130	72 (64.3-79.7)	96	81.9 (74.2-89.6)	92	72.6 (63.5-81.7)	103	68.8 (59.9-77.7)	99	65.1 (55.7-74.5)
Dark brown/black	159	67.7 (60.4-75.0)	113	79.8 (72.4-87.2)	128	70.9 (63.0-78.8)	116	64.4 (55.7-73.1)	120	55.9 (47.0-64.8)
Eye color										
Blue/grey	143	72.3 (65.0-79.6)	109	84 (77.1-90.9)	102	73.5 (64.9-82.1)	108	66.1 (57.2-75.0)	110	65.7 (56.8-74.6)
Green/hazel	104	73.8 (65.3-82.3)	78	83.1 (74.8-91.4)	82	74.8 (65.4-84.2)	75	72.3 (62.2-82.4)	77	64.9 (54.2-75.6)
Brown/black	128	67.2 (59.1-75.3)	94	79.3 (71.1-87.5)	95	69.1 (59.8-78.4)	100	66.9 (57.7-76.1)	95	53.5 (43.5-63.5)
Moles										
None (0)	30	70 (53.6-86.4)	24	75.1 (57.8-92.4)	24	76.1 (59.0-93.2)	21	70.3 (50.8-89.8)	21	57.1 (35.9-78.3)
A few (1-19)	188	68.7 (62.1-75.3)	141	79.9 (73.3-86.5)	139	71.3 (63.8-78.8)	141	64.5 (56.6-72.4)	143	59.0 (50.9-67.1)
Some (20-50)	118	73.7 (65.8-81.6)	88	85.8 (78.5-93.1)	87	71.5 (62.0-81.0)	85	71.5 (61.9-81.1)	94	66.2 (56.6-75.8)
Many (>50)	39	74.6 (60.9-88.3)	28	88.3 (76.4-100.0)	29	76.7 (61.3-92.1)	36	72.1 (57.4-86.8)	24	60.2 (40.6-79.8)
Freckles										
None (0)	90	67.1 (57.4-76.8)	60	78 (67.5-88.5)	71	69.2 (58.5-79.9)	68	64.5 (53.1-75.9)	71	58.2 (46.7-69.7)
A few (1-19)	154	68.4 (61.1-75.7)	117	80.9 (73.8-88.0)	109	69.4 (60.7-78.1)	120	66.3 (57.8-74.8)	116	57.2 (48.2-66.2)
Some (20-50)	79	75.7 (66.2-85.2)	65	85.9 (77.4-94.4)	61	78.0 (67.6-88.4)	54	71.2 (59.1-83.3)	57	65.7 (53.4-78.0)
Many (>50)	52	78 (66.7-89.3)	39	86 (75.1-96.9)	38	77.7 (64.5-90.9)	41	74.7 (61.4-88.0)	38	73.5 (59.5-87.5)
Skin tan										
Burn and not tan afterwards	125	74.7 (67.1-82.3)	104	84.7 (77.8-91.6)	86	75.6 (66.5-84.7)	94	74.4 (65.6-83.2)	91	62.7 (52.8-72.6)
Burn then tan	164	72.2 (65.3-79.1)	121	83.3 (76.7-89.9)	124	71.8 (63.9-79.7)	127	67.9 (59.8-76.0)	120	65.8 (57.3-74.3)
Tan without burning	86	63.2 (53.0-73.4)	56	75 (63.7-86.3)	69	69.3 (58.4-80.2)	62	58.5 (46.2-70.8)	71	52.2 (40.6-63.8)
Suntan past 12 months										
Never	237	71.5 (65.8-77.2)	181	82.9 (77.4-88.4)	175	72.5 (65.9-79.1)	175	67.9 (61.0-74.8)	180	62.4 (55.3-69.5)
Once	34	70.2 (54.8-85.6)	22	83.6 (68.1-99.1)	27	71.3 (54.2-88.4)	26	69.8 (52.2-87.4)	27	58.5 (39.9-77.1)
2-5 times	70	70.8 (60.1-81.5)	55	82.4 (72.3-92.5)	51	70.6 (58.1-83.1)	55	69.0 (56.8-81.2)	49	60.2 (46.5-73.9)
≥6 times	25	72.9 (55.5-90.3)	17	79 (59.6-98.4)	18	80.1 (61.7-98.5)	19	71.4 (51.1-91.7)	21	63.1 (42.5-83.7)
Don't know/unsure	9	55.5 (23.0-88.0)	6	60.7 (21.6-99.8)	8	66.1 (33.3-98.9)	8	48.6 (14.0-83.2)	5	43.4 (0.0-86.8)
Sunburn past four weeks										
Never	852[2]	72.9 (72.0-73.8)	174	81 (75.2-86.8)	213	75.7 (69.9-81.5)	231	70.8 (64.9-76.7)	234	66.3 (60.2-72.4)
≥Once	224	76.1 (70.5-81.7)	106	83.9 (76.9-90.9)	56	69.9 (57.9-81.9)	40	66.9 (52.3-81.5)	22	71.2 (52.3-90.1)
Don't know	49	14.1 (4.4-23.8)	1	100 (100.0-100.0)	10	14.0 (0.0-35.5)	12	17.6 (0.0-39.1)	26	9.2 (0.0-20.3)
SPH[3] past four weeks										
<3	221[4]	70.0 (68.1-71.9)	90	81.3 (73.2-89.4)	52	64.0 (51.0-77.0)	36	61.5 (45.6-77.4)	43	61.0 (46.4-75.6)
≥3	856	74.4 (71.5-77.3)	191	82.6 (77.2-88.0)	217	77.0 (71.4-82.6)	236	71.3 (65.5-77.1)	212	67.9 (61.6-74.2)
Missing Data	48	13.5 (3.8-23.2)	0	-	10	14.0 (0.0-35.5)	11	19.2 (0.0-42.5)	27	11.0 (0.0-22.8)

1. Total numbers of participants for different interventions are the sum of participants over four periods; 2. Total numbers of participants with different sunburn categorize over the past four weeks are the sum of participants over four periods; 3. SPH: Sun protection habits index, ranged from 1-5; 4. Total numbers of participants with different SPH over the past four weeks are the sum of participants over four periods.

Table 3. Crude and adjusted probabilities of having engagement rate of <70%, 70%-<100%, and 100% by treatment, period, and group.

	Period 1		Period 2		Period 3		Period 4	
	Crude*	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
Intervention B								
<70%	18.3 (10.4-26.2)	21.8 (14.1-29.4)	46.8 (36.7-56.9)	43.4 (33.5-53.2)	42.7 (32.8-52.7)	42.1 (32.5-51.8)	34.8 (25.0-44.6)	34.6 (25.2-43.9)
70%-<100%	22.6 (14.7-30.5)	22.2 (13.9-30.5)	29.8 (19.6-39.9)	31.3 (21.7-40.9)	29.2 (19.2-39.1)	29.3 (20.2-38.3)	30.4 (20.6-40.2)	30.8 (21.3-40.3)
100%	59.1 (51.2-67.0)	56.1 (46.4-65.7)	23.4 (13.3-33.5)	25.3 (16.2-34.4)	28.1 (18.2-38.1)	28.6 (19.7-37.5)	34.8 (25.0-44.6)	34.7 (25.3-44.1)
Intervention C								
<70%	13.0 (6.1-20.0)	15.7 (8.7-22.6)	23.7 (15.0-32.3)	25.9 (17.6-34.2)	41.5 (31.5-51.5)	41.0 (31.2-50.8)	43.8 (33.8-53.7)	37.3 (27.4-47.2)
70%-<100%	52.2 (45.3-59.1)	50.7 (40.5-60.9)	45.2 (36.5-53.8)	44.5 (34.5-54.5)	40.4 (30.4-50.4)	40.7 (30.8-50.5)	33.3 (23.4-43.3)	36.7 (26.6-46.7)
100%	34.8 (27.9-41.7)	33.6 (24.2-43.0)	31.2 (22.5-39.9)	29.6 (20.6-38.5)	18.1 (8.1-28.1)	18.4 (10.6-26.2)	22.9 (12.9-32.9)	26.1 (16.7-35.4)
Intervention D								
<70%	28.1 (19.1-37.2)	30.2 (21.5-38.9)	28.3 (19.0-37.5)	31.0 (21.7-40.3)	30.1 (20.7-39.5)	33.3 (23.6-43.0)	68.1 (58.6-77.6)	66.0 (56.3-75.7)
70%-<100%	45.8 (36.8-54.9)	44.2 (34.5-54.0)	45.7 (36.4-54.9)	44.2 (34.2-54.3)	37.6 (28.3-47.0)	36.7 (26.8-46.5)	21.3 (11.8-30.8)	22.4 (13.8-31.0)
100%	26.0 (17.0-35.1)	25.6 (16.9-34.2)	26.1 (16.8-35.3)	24.8 (16.3-33.2)	32.3 (22.9-41.6)	30.1 (20.9-39.2)	10.6 (1.2-20.1)	11.6 (4.9-18.3)

Group 1 was shadowed in red, group 2 was shadowed in yellow, group 3 was shadowed in blue, group 4 was shadowed in grey.
Intervention B: Interactive messages 3 times a week for 4 weeks.
Intervention C: Personalized and Interactive daily messages for first 2 weeks; then 3 times a week messaging for another 2 weeks (decreasing frequency to support habit formation).
Intervention D: Personalized and Interactive 3 times a week for 2 weeks at start; then daily messaging for last 2 weeks (increasing frequency to improve maintenance of the new behaviors).
Crude results were un-adjusted observed proportions. Adjusted results were generated using a multinominal logistic model (Model 2), including income, sun protection habits index over the past four weeks, period, intervention, and the interaction between period and intervention as predictor variables.

Table 4. Proportion of responses to interactive messages

COM-B model components	Text message	Answers
'Capability' Individual's psychological and physical ability (including knowledge and skills)	Can you be sunburnt indoors? Text back yes or no.	Yes: 201/375 (53.60%) No: 53/375 (14.13%) NR: 121/375 (32.27%)
	It is too late for me to stay out of the sun, the damage is already done. Text back true or false.	True: 7/138 (5.07%) False: 96/138 (69.57%) NR: 35/138 (25.36%)
	Does the sun age your skin? Text back yes or no.	Yes: 178/237 (75.11%) No: 7/237 (2.95%) NR: 52/237 (21.94%)
	Have you heard of photoaging? Text back yes or no.	Yes: 55/309 (17.80%) No: 190/309 (61.49%) NR: 64/309 (20.71%)
	The closer the weave in a material the better it is for sun protection. Text back true or false.	True: 254/375 (67.73%) False: 17/375 (4.53%) NR: 104/375 (27.73%)
	If a sunscreen says 4 hours water resistant on the label, do you only apply every 4 hours? Text back yes or no.	Yes: 96/375 (25.60%) No: 178/375 (47.47%) NR: 101/375 (26.93%)
	Is everyone susceptible to skin cancer? Text back yes or no.	Yes: 270/375 (72.00%) No: 7/375 (1.87%) NR: 98/375 (26.13%)
	Can you get sunburnt on a cloudy day? Text back yes or no.	Yes: 302/375 (80.53%) No: 6/375 (1.60%) NR: 67/375 (17.87%)
	Sunscreen is not necessary when using cosmetics with SPF. Text back true or false.	True: 55/309 (17.80%) False: 167/309 (54.04%) NR: 87/309 (28.16%)
	If you tan but don't burn, you don't need to bother with sun protection. Text back true or false.	True: 8/375 (2.13%) False: 259/375 (69.07%) NR: 108/375 (28.80%)
	Did you know there are 3 main types of skin cancer? Text back yes or no.	Yes: 89/375 (23.73%) No: 150/375 (40.00%) NR: 136/375 (36.27%)
	You can stay out longer in the sun when you are wearing SPF50+ than you can with SPF30+. Text back true or false.	True: 74/375 (19.73%) False: 142/375 (37.87%) NR: 159/375 (42.40%)
	Will a "base tan" offer protection from further sun-induced skin damage even if you have [skin type] colored skin? Text back yes or no.	Yes: 9/88 (10.23%) No: 36/88 (40.91%) Extra: 2/88 (2.27%) NR: 41/88 (46.59%)
	Very fair skin type makes you highly susceptible to sunburn. Text back true or false.	True: 173/287 (60.28%) False: 4/287 (1.39%) NR: 110/287 (38.33%)
	You can get burnt in the car through a window? Text back true or false.	True: 238/375 (63.47%) False: 4/375 (1.07%) NR: 133/375 (35.47%)
	Do you know what windburn is? /Is there such a thing as windburn? Text back yes or no.	Yes: 212/375 (56.53%) No: 51/375 (13.60%) Extra: 1/375 (0.27%) NR: 111/375 (29.60%)
'Motivation' Automatic and reflective processes (including emotions, evaluations, and plans)	In your experience is sunscreen sticky and greasy?	Yes: 235/375 (62.67%) No: 49/375 (13.07%) Extra: 1/375 (0.27%) NR: 90/375 (24.00%)
	Do you worry about getting enough Vitamin D? Text back yes or no.	Yes: 97/375 (25.87%) No: 165/375 (44.00%) NR: 113/375 (30.13%)
	People who have had severe, blistering sunburns are at higher risk of skin cancer. Do you worry about skin cancer? Text back yes or no.	Yes: 103/158 (65.19%) No: 16/158 (10.13%) NR: 39/158 (24.68%)
	Even mild sunburns in the past means you are at higher risk of skin cancer. Do you worry about your skin cancer risk? Text back yes or no	Yes: 127/217 (58.52%) No: 20/217 (9.22%) NR: 70/217 (32.26%)

'Opportunity' Physical and social environment	Who is a good role model for limiting sun exposure? Text back family or friend or colleague or GP.	Family: 133/375 (35.47%) Friend: 39/375 (10.40%) Colleague: 9/375 (2.40%) GP: 42/375 (11.20%) Extra: 12/375 (3.20%) NR: 140/375 (37.33%)
	Are you always rushing in the mornings? Text back yes or no.	Yes: 212/375 (56.53%) No: 90/375 (24.00%) NR: 73/375 (19.47%)
	Where do you store your sunscreen? Text back bathroom or bag or car.	Bathroom: 191/375 (50.93%) Bag: 38/375 (10.13%) Car: 25/375 (6.67%) Extra: 16/375 (4.27%) NR: 105/375 (28.00%)
	Will you be going outdoors this weekend? Text back yes or no.	Yes: 213/375 (56.80%) No: 62/375 (16.53%) NR: 100/375 (26.67%)
	Planning activities outside with your mates this weekend? Text back yes or no.	Yes: 172/375 (45.87%) No: 114/375 (30.40%) NR: 89/375 (23.73%)
'Behavior' Sun protection behaviors	How frequently do you think you should apply sunscreen when outdoors during one day? Text back once or multiple.	Once: 18/375 (4.80%) Multiple: 250/375 (66.67%) Extra: 1/375 (0.27%) NR: 106/375 (28.27%)
	Have you recently checked the date of expiry on your sunscreen bottle? Text your response yes or no.	Yes: 72/375 (19.20%) No: 182/375 (48.53%) NR: 121/375 (32.27%)
	What is your most common body part that gets sunburnt? Text back head or back or arms or torso or legs.	Head: 87/375 (23.20%) Back: 56/375 (14.93%) Arms: 94/375 (25.07%) Torso: 7/375 (1.87%) Legs: 5/375 (1.33%) Extra: 14/375 (3.73%) NR: 112/375 (29.87%)
	Do you check the weather forecast before heading outside each day? Text back yes or no.	Yes: 117/375 (31.20%) No: 148/375 (39.47%) NR: 110/375 (29.33%)
	Do you describe your skin as, "dry, cracked, scaly, blistered, and scarred"? Text back yes or no.	Yes: 12/66 (18.18%) No: 39/66 (59.09%) NR: 15/66 (22.73%)
	At work how many hours are you in the sun? Text back under 1 or 1-3 or over 3.	Under 1 hour: 8/57 (14.04%) 1-3 hours: 10/57 (17.54%) Over 3 hours: 17/57 (29.82%) NR: 22/57 (38.60%)
	Do you have your lunch break outdoors in the sun? Text back yes or no.	Yes: 41/318 (12.89%) No: 211/318 (66.35%) NR: 66/318 (20.76%)
	How long before you go outside should you put on sunscreen? Text back 20 mins or just before or outside.	20 mins: 228/375 (60.80%) Just before: 36/375 (9.60%) Outside: 3/375 (0.80%) NR: 108/375 (28.80%)
	Do you reapply sunscreen when outdoors for longer than 2 hrs during 9-3pm? Text back yes or no.	Yes: 160/375 (42.67%) No: 97/375 (25.87%) NR: 118/375 (31.47%)
	Do you check your skin for skin cancer? Text back yes or no.	Yes: 137/375 (36.53%) No: 116/375 (30.93%) NR: 122/375 (32.53%)
	What SPF are you wearing today to protect your skin from UV rays? Text back 15+ or 30+ or 50+ or none.	15+: 28/375 (7.47%) 30+: 41/375 (10.93%) 50+: 74/375 (19.73%) None: 112/375 (29.87%) NR: 120/375 (32.00%)
	Have you been sunburnt after using sunscreen? Text back yes or no.	Yes: 218/375 (58.13%) No: 72/375 (19.20%) Extra: 1/375 (0.27%) NR: 84/375 (22.40%)
	Do you often forget to apply sunscreen? Text back yes or no.	Yes: 200/375 (53.33%) No: 79/375 (21.07%) Extra: 1/375 (0.27%) NR: 95/375 (25.33%)
No response (NR): Number of participants who did not respond to the message; Extra: Number of participants whose responses were outside the options provided (e.g. 'yes' or 'no'), such as "not sure".		

Supplementary data

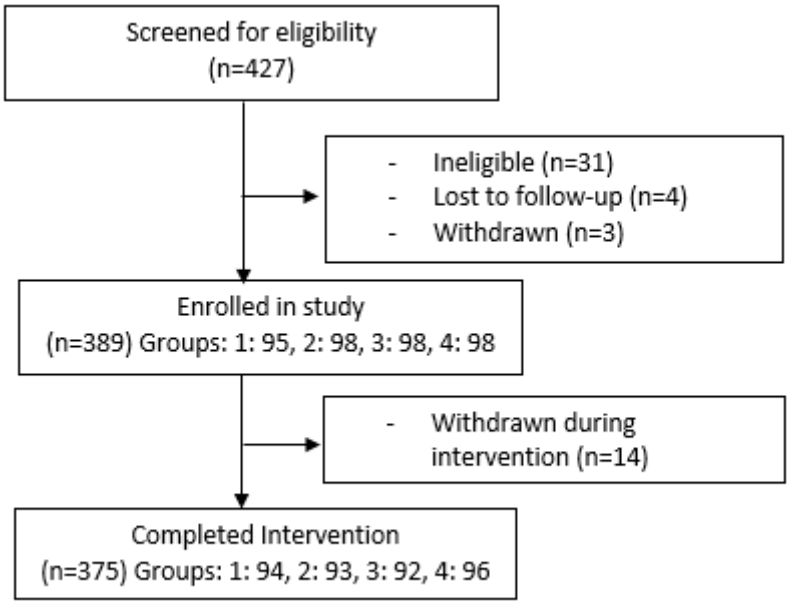

Figure S1. Participant Flow Chart

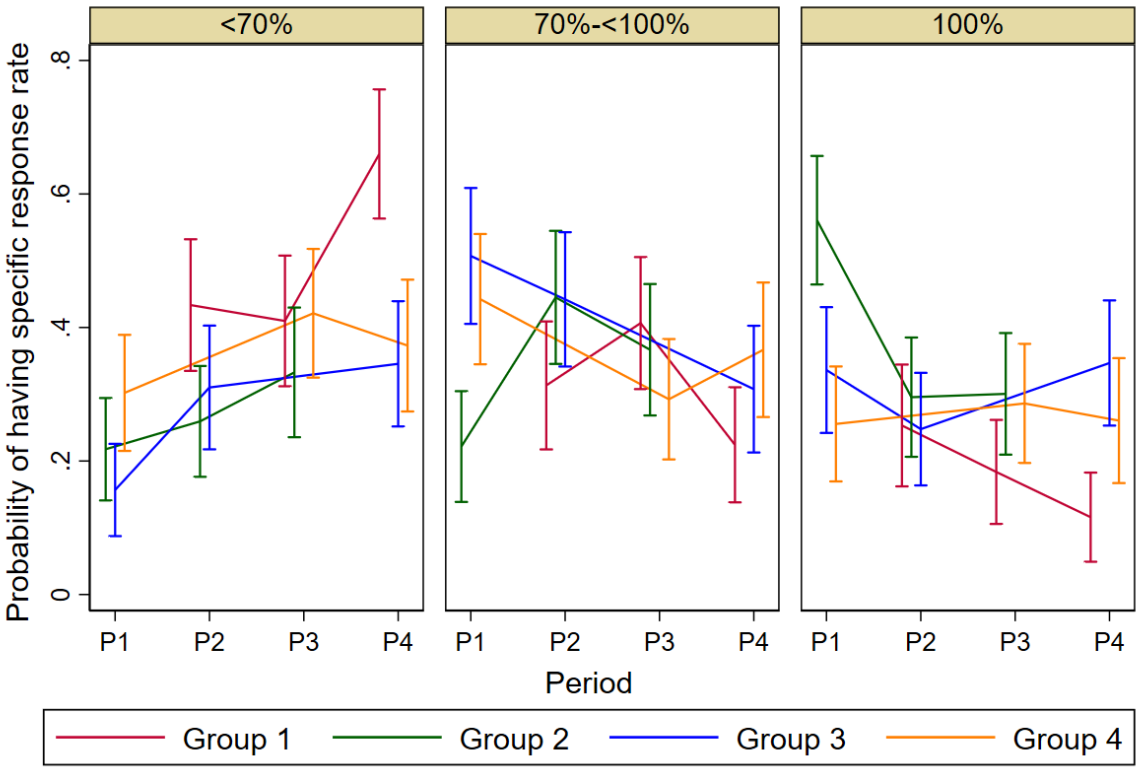

Figure S2. Probability of having response rate <70%, 70%-<100%, or 100% by period and group.

Note: Results were generated using a multinomial logistic regression model (Model 1), including income, sun protection habits index over the past four weeks, period, group, and the interaction between period and group as predictor variables. The vertical lines represent the 95% confidence intervals.

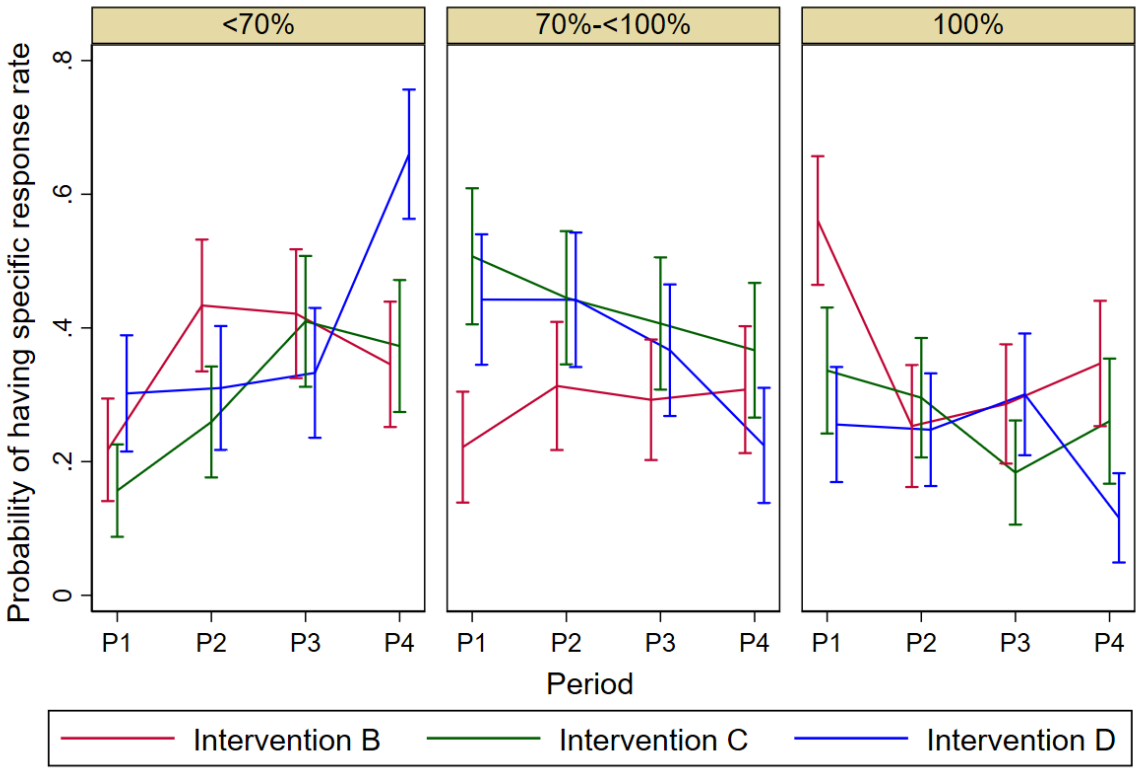

Figure S3. Probability of having response rate <70%, 70%-<100%, or 100% by period and intervention.

Note: Results were generated using a multinomial logistic regression model (Model 2), including income, sun protection habits index over the past four weeks, period, intervention, and the interaction between period and intervention as predictor variables. The vertical lines represent the 95% confidence intervals.

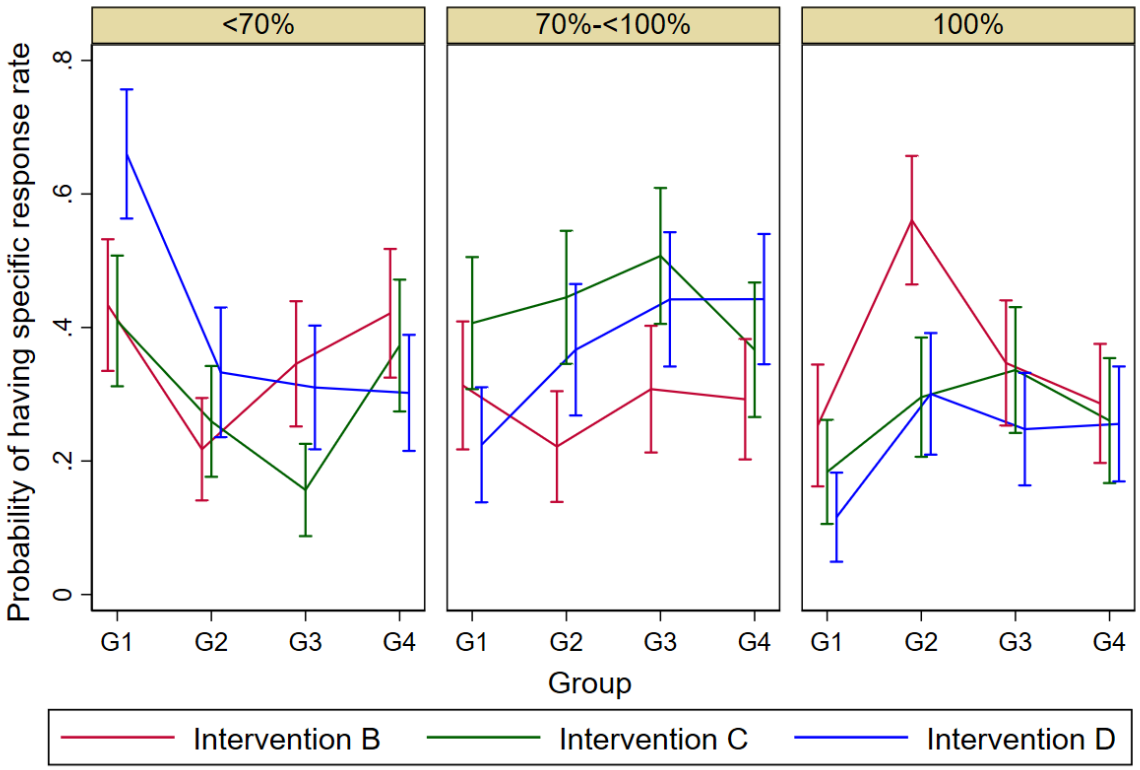

Figure S4. Probability of having response rate <70%, 70%-<100%, or 100% by group (G) and intervention.

Note: Results were generated using a multinomial logistic regression model (Model 3), including income, sun protection habits index over the past four weeks, intervention, group, and the interaction between intervention and group as predictor variables. The vertical lines represent the 95% confidence intervals.

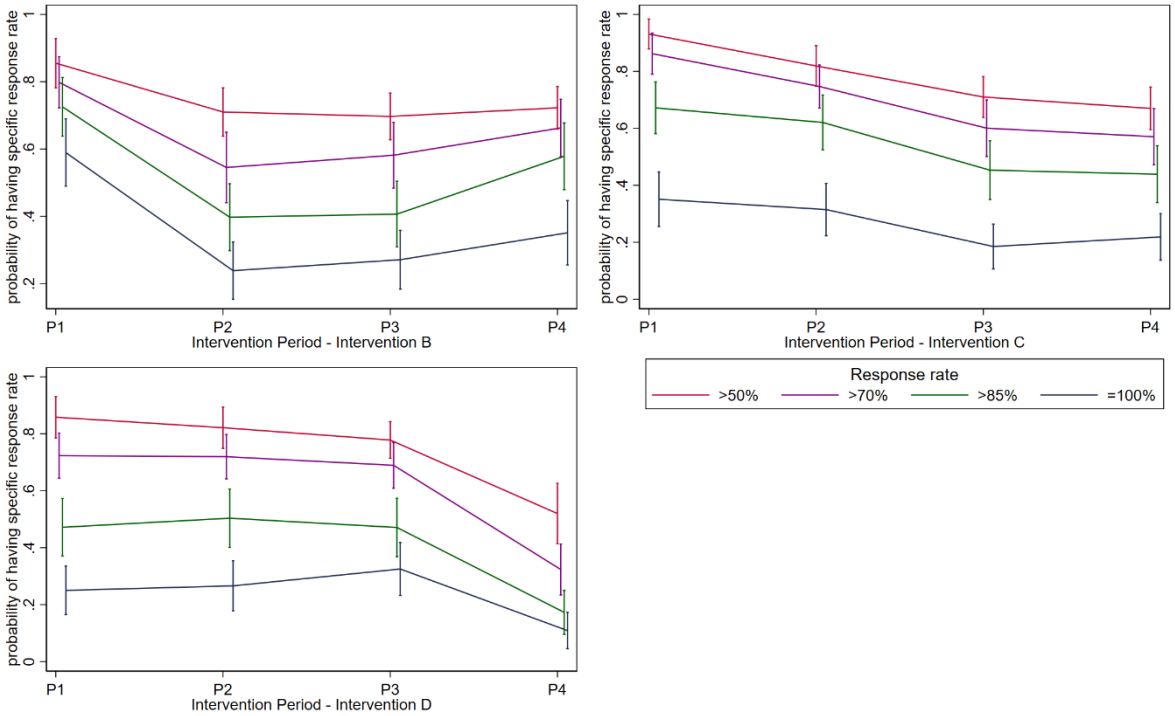

Figure S5. Probabilities of having response rate >50%, >70%, >85%, or =100% by period and intervention.

Note: Results were generated using four logistic regression models with different cut points for the outcome variable. The vertical lines represent the 95% confidence intervals.

Table S1. Relative risk ratio[1] of having response rate of <70%, 70%-<100%, and 100% by different periods and groups

	<70%[2]		**70%-<100%**		**100%**	
	RRR (95% CI)	p	RRR (95% CI)	p	RRR (95% CI)	p
Period				**<0.01[3]**		**<0.01**
Group 1						
Period 2	-	-	1	-	1	-
Period 3	-	-	1.38 (0.82-2.31)	0.22	0.77 (0.45-1.31)	0.33
Period 4	-	-	0.45 (0.25-0.82)	0.01	0.28 (0.14-0.59)	<0.01
Group 2						
Period 1	-	-	1	-	1	-
Period 2	-	-	1.60 (0.79-3.25)	0.19	0.41(0.23-0.74)	<0.01
Period 3	-	-	0.99 (0.47-2.10)	0.99	0.31 (0.17-0.57)	<0.01
Group 3						
Period 1	-	-	1	-	1	-
Period 2	-	-	0.39 (0.19-0.78)	0.01	0.32 (0.17-0.63)	<0.01
Period 4	-	-	0.24 (0.11-0.51)	<0.01	0.40 (0.19-0.84)	0.02
Group 4						
Period 1	-	-	1	-	1	-
Period 3	-	-	0.46 (0.25-0.82)	0.01	0.77 (0.48-1.24)	0.28
Period 4	-	-	0.65 (0.38-1.11)	0.12	0.80 (0.48-1.35)	0.40
Income				**0.29**		**0.01**
≤$20,799	-	-	1		1	
$20,800-$51,599	-	-	0.90 (0.53-1.54)	0.71	0.81 (0.42-1.57)	0.53
$52,000-$90,999	-	-	0.99 (0.62-1.59)	0.98	0.73 (0.42-1.26)	0.26
≥$91,000	-	-	0.81 (0.42-1.56)	0.54	0.35 (0.17-0.77)	0.01
Prefer not to answer	-	-	0.55 (0.25-1.21)	0.14	0.34 (0.12-0.93)	0.04
SPH past four weeks				**<0.01**		**<0.01**
<3	-	-	1		1	
≥3	-	-	1.37 (0.92-2.03)	0.13	1.55 (0.96-2.50)	0.07
Missing data	-	-	0.06 (0.01-0.25)	<0.01	0.00 (0.00-0.00)	<0.01

1. Results were generated using Model 1, which was adjusted for period, group, interaction between period and group, income, and sun protection habits (SPH) over the past four weeks; 2. Response rate <70% is reference group; 3. P values in bold are the overall p values for the corresponding variables.

Table S2. Relative risk ratio[1] of having response rate of <70%, 70%-<100%, and 100% by different periods and interventions

	<70%[2]		**70%-<100%**		**100%**	
	RRR (95% CI)	p	RRR (95% CI)	p	RRR (95% CI)	p
Intervention				**0.02[3]**		**0.03**
Period 1						
Intervention B	-	-	1	-	1	-
Intervention C	-	-	3.34 (1.36-8.21)	0.01	0.87 (0.36-2.06)	0.75
Intervention D	-	-	1.34 (0.60-2.95)	0.48	0.30 (0.14-0.65)	<0.01
Period 2						
Intervention B	-	-	1	-	1	-
Intervention C	-	-	2.55 (1.24-5.25)	0.01	2.11 (0.96-4.64)	0.06
Intervention D	-	-	2.06 (1.01-4.19)	0.05	1.43 (0.65-3.14)	0.37
Period 3						
Intervention B	-	-	1	-	1	-
Intervention C	-	-	1.43 (0.72-2.84)	0.31	0.66 (0.30-1.43)	0.29
Intervention D	-	-	1.63 (0.80-3.36)	0.18	1.38 (0.65-2.90)	0.40
Period 4						
Intervention B	-	-	1	-	1	-
Intervention C	-	-	1.09 (0.53-2.25)	0.82	0.68 (0.32-1.47)	0.33
Intervention D	-	-	0.35 (0.17-0.74)	0.01	0.16 (0.07-0.37)	<0.01
Income				**0.29**		**0.01**
≤$20,799	-	-	1	-	1	-
$20,800-$51,599	-	-	0.90 (0.53-1.54)	0.71	0.81 (0.42-1.57)	0.53
$52,000-$90,999	-	-	0.99 (0.62-1.59)	0.98	0.73 (0.42-1.26)	0.26
≥$91,000	-	-	0.81 (0.42-1.56)	0.54	0.35 (0.17-0.77)	0.01
Prefer not to answer	-	-	0.55 (0.25-1.21)	0.14	0.34 (0.12-0.93)	0.04
SPH past four weeks				**<0.01**		**<0.01**
<3	-	-	1	-	1	-
≥3	-	-	1.37 (0.92-2.03)	0.13	1.55 (0.96-2.50)	0.07
Missing data	-	-	0.06 (0.01-0.25)	<0.01	0.00 (0.00-0.00)	<0.01

1. Results were generated using Model 2, which was adjusted for intervention, period, interaction between intervention and period, income, and sun protection habits (SPH) over the past four weeks; 2. Response rate <70% is reference group; 3. P values in bold are the overall p values for the corresponding variables.

Table S3. Relative risk ratio[1] of having response rate of <70%, 70%-<100%, and 100% by groups and interventions

	<70%[2]		**70%-<100%**		**100%**	
	RRR (95% CI)	p	RRR (95% CI)	p	RRR (95% CI)	p
Group				**<0.01[3]**		**<0.01**
Intervention B						
Group 1	-	-	1	-	1	-
Group 2	-	-	1.59 (0.71-3.56)	0.26	5.12 (2.35-11.1)	<0.01
Group 3	-	-	1.27 (0.61-2.64)	0.52	1.79 (0.85-3.76)	0.13
Group 4	-	-	0.97 (0.48-1.95)	0.92	1.17 (0.56-2.46)	0.68
Intervention C						
Group 1	-	-	1	-	1	-
Group 2	-	-	1.85 (0.91-3.74)	0.09	2.75 (1.21-6.24)	0.02
Group 3	-	-	3.84 (1.72-8.57)	<0.01	5.78 (2.35-14.2)	<0.01
Group 4	-	-	1.00 (0.50-2.01)	0.99	1.59 (0.70-3.62)	0.27
Intervention D						
Group 1	-	-	1	-	1	-
Group 2	-	-	3.51 (1.68-7.34)	<0.01	5.68 (2.37-13.64)	<0.01
Group 3	-	-	4.57 (2.22-9.41)	<0.01	5.05 (2.08-12.24)	<0.01
Group 4	-	-	4.71 (2.32-9.60)	<0.01	5.37 (2.25-12.82)	<0.01
Income				**0.29**		**0.01**
≤$20,799	-	-	1	-	1	-
$20,800-$51,599	-	-	0.90 (0.53-1.54)	0.71	0.81 (0.42-1.57)	0.53
$52,000-$90,999	-	-	0.99 (0.62-1.59)	0.98	0.73 (0.42-1.26)	0.26
≥$91,000	-	-	0.81 (0.42-1.56)	0.54	0.35 (0.17-0.77)	0.01
Prefer not to answer	-	-	0.55 (0.25-1.21)	0.14	0.34 (0.12-0.93)	0.04
SPH past four weeks				**<0.01**		**<0.01**
<3	-	-	1	-	1	-
≥3	-	-	1.37 (0.92-2.03)	0.13	1.55 (0.96-2.50)	0.07
Missing data	-	-	0.06 (0.01-0.25)	<0.01	0.00 (0.00-0.00)	<0.01

1. Results were generated using Model 3, which was adjusted for group, intervention, interaction between group and intervention, income, and sun protection habits (SPH) over the past four weeks; 2. Response rate <70% is reference group; 3. P values in bold are the overall p values for the corresponding variables.