Eur J Ageing (2016) 13:251–257
DOI 10.1007/s10433-016-0368-1

ORIGINAL INVESTIGATION

Positive messages enhance older adults' motivation and recognition memory for physical activity programmes

Nanna Notthoff[1] · Peter Klomp[2,3] · Friederike Doerwald[3] · Susanne Scheibe[3]

Published online: 9 March 2016

Abstract Although physical activity is an effective way to cope with ageing-related impairments, few older people are motivated to turn their sedentary lifestyle into an active one. Recent evidence suggests that walking can be more effectively promoted in older adults with positive messages about the benefits of walking than with negative messages about the risks of inactivity. This study examined motivation and memory as the supposed mechanisms underlying the greater effectiveness of positively framed compared to negatively framed messages for promoting activity. Older adults ($N = 53$, age 60–87 years) were introduced to six physical activity programmes that were randomly paired with either positively framed or negatively framed messages. Participants indicated how motivated they were to participate in each programme by providing ratings on attractiveness, suitability, capability and intention. They also completed surprise free recall and recognition tests. Respondents felt more motivated to participate in physical activity programmes paired with positively framed messages than in those with negatively framed ones. They also had better recognition memory for positively framed than negatively framed messages, and misremembered negatively framed messages to be positively framed. Findings support the notion that socioemotional selectivity theory—a theory of age-related changes in motivation—is a useful basis for health intervention design.

Keywords Physical activity · Health message framing · Positivity effect · Socioemotional selectivity theory · Ageing

Responsible editor: D.J.H. Deeg.

✉ Nanna Notthoff
notthoff@alumni.stanford.edu

Peter Klomp
j.p.klomp@pl.hanze.nl

Friederike Doerwald
f.doerwald@rug.nl

Susanne Scheibe
s.scheibe@rug.nl

[1] Faculty of Life Sciences, Institute of Psychology, Humboldt University Berlin, Unter den Linden 6, 10099 Berlin, Germany

[2] Department of Healthcare, University of Applied Science, Eyssoniusplein 18, 9714 CE Groningen, The Netherlands

[3] Department of Psychology, University of Groningen, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands

Regular engagement in physical activity has many benefits, including prevention of diseases (O'Donovan et al. 2010) and disability (Visser et al. 2002), preserved cognitive functioning (Hertzog et al. 2008) and improved well-being (Withall et al. 2014). This is true even when people start exercising at advanced age (Hamer et al. 2013). Because of these benefits, older adults are frequently exposed to messages recommending physical activity, whether through their physician, sports centres, or media campaigns. Yet, many older people remain inactive; for example, 58 % of Europeans over the age of 55 years never participate in physical activity (European Commission 2014). This raises the question of how the effectiveness of physical activity promotion messages targeting older adults can be enhanced.

Recent research shows that message framing which takes into account age differences in motivation effectively promotes walking in older adults (Notthoff and Carstensen 2014). In two studies, older adults who received *positively framed* messages about the benefits of walking increased walking significantly more than their peers who received

negatively framed messages about the risks of failing to walk more. The studies were stimulated by socioemotional selectivity theory, according to which positive information is preferentially processed and better remembered by older adults because it matches their motivational orientation to enhance present well-being (Carstensen et al. 1999). The preferential processing of and memory for positive over negative information by older compared to younger adults, a phenomenon coined the positivity effect is well documented (Reed and Carstensen 2012). Several theoretical approaches speak to the differential effectiveness of positive and negative message framing for health behaviour promotion (e.g. Covey 2014; Mann et al. 2004; Rothman and Salovey 1997; Sherman et al. 2006). For this study, we chose to adopt socioemotional selectivity theory, and specifically the positivity effect, as a theoretical framework due to its relevance for motivation in older adults.

Prior studies that applied the positivity effect to the processing of health information found that older adults rated positively framed health messages as more informative and remembered them better than negatively framed ones (Shamaskin et al. 2010). Older adults also focused more on positive than negative attributes when making health-related decisions, such as picking a health plan or physician (Löckenhoff and Carstensen 2007). Based on these findings, Notthoff and Carstensen (2014) argued that preferential processing of positive information underlies the higher effectiveness of positively framed compared to negatively framed messages to promote walking in older adults. So far, this mechanism has not been directly tested in the context of physical activity promotion; neither Notthoff and Carstensen (2014) nor other studies on physical activity promotion measured preferential processing, for instance, how positively framed compared to negatively framed messages affect motivation for physical activity programmes or memory for message content.

The current study extends the research on applying the positivity effect to designing effective physical activity promotion messages for older adults in theoretical and practical ways. From a theoretical perspective, we tested two mechanisms presumably underlying the greater effectiveness of positively framed over negatively framed messages—the level of initial motivation for the recommended activity and memory for the message content. From a practical perspective, we tested whether positively framed messages effectively promote motivation and memory for a range of physical activity programmes. Previous related interventions focused on walking only. Specifically, we hypothesized that older adults perceive positively framed messages about various physical activity programmes as more motivating (Hypothesis 1) and remember them better (Hypothesis 2) than negatively framed messages.

Method

Participants

The study was approved by the ethics review committee of the University of Groningen. Participants were recruited by distributing flyers to 850 homes in a small Dutch city with a large proportion of older residents, informing inhabitants that they would be approached to participate in an evaluation of physical activity programmes for older adults. Fifteen trained research assistants who were physiotherapy students of a local University of Applied Science visited the homes of approximately 400 potential participants; 60 agreed to participate. We excluded six participants who failed to complete the survey and one participant due to technical failure with the experimental manipulation from the analyses. Participation was voluntary. As a reward, participants received vouchers for two free sessions in the programme of their choice out of the ones they evaluated.

The final sample comprised 53 older adults aged 60–87 years ($M = 72.58 \pm 8.38$; 53 % women). A small proportion of the sample (9.4 %) only completed primary education, 60.5 % secondary education, and 30.2 % held a Bachelor's or Master's degree. Of the participants, 26.4 % reported an annual household income at below-average level (defined as ca. €30,000), 35.8 % at about average level, and 22.7 % at above-average level (15.1 % did not indicate their income). Participants were in good physical ($M = 61.84 \pm 16.79$) and mental health ($M = 80.63 \pm 14.56$; scores ranged from 0 to 100; higher scores indicate better health) as measured by the 12-item version of the SF-36 (Ware et al. 1996). They scored between 15 and 59 points ($M = 34.94 \pm 10.86$) on the Digit Symbol Coding test and between 9 and 42 ($M = 19.78 \pm 6.67$) on the Animal Naming task; these scores represent normal cognitive capacities (Ardila 2007; Tombaugh et al. 1999).

Materials and procedure

Six 30-sec films were recorded in collaboration with a local physiotherapy practice that offers physical activity programmes for older adults. Each film presented a particular programme: Gaming, Tai Chi, Nordic Walking, Senior Fit, Zumba, and Yoga. For each film, we constructed a positively framed and a negatively framed written message (see "Appendix"). Positively framed messages focused on the benefits people could gain from participating in the programme; negatively framed messages emphasized the negative consequences of not participating.

After giving informed consent, reporting information on demographics and health, and completing two cognitive tests, participants viewed the six films and the associated

messages. For each participant, three films were randomly paired with a positively framed message and three with a negatively framed one; film order was randomized. Participants had approximately 1 min to watch each film and read the associated message. They then completed ratings regarding *attractiveness* ('How attractive do you find this programme?'), *suitability* ('How well would this programme suit you?'), *capability* ('How capable are you to follow this programme?') and *intention to participate* ('Would you like to participate in a trial session of this programme?') using 5-point Likert scales (1 = *not at all*, 5 = *completely*). The first three items were constructed for the purpose of this study (due to a lack of suitable measures in the literature) based on Eccle's (2002) expectancy-value theory; the fourth item measured intention, a strong predictor of behaviour (Bandura 1997). Detailed item analyses indicated that three of the items (attractiveness, suitability and intention) correlated positively with each other for all six programmes, but in 9 out of 18 cases were not correlated or negatively correlated with the item assessing capability. Moreover, this latter item substantially decreased the internal consistency and was therefore excluded.[1] The resulting internal consistencies ranged from 0.75 to 0.89. For each film, we calculated an index of motivation with the three remaining items. Further aggregation yielded two motivation scores per person, one for films paired with positively framed messages and one for films paired with negatively framed messages.

After watching the films and providing motivation ratings, participants completed surprise free recall and recognition tests. In the free recall task, participants were asked to name the six physical activity programmes. We calculated the proportion of correctly named programmes paired with positively framed and negatively framed messages, respectively (possible range from 0 to 1). In the recognition task, participants read the positively framed and negatively framed message for each film and were asked to identify which of the messages they had seen earlier. We used the proportion of correctly recognized positively framed and negatively framed message-film pairs (hits) as indices of recognition memory (possible range from 0 to 1).

[1] Additional analyses with the single capability item yielded no significant differences between programmes paired with positively framed messages ($M = 3.39$, SD = 1.26) and programmes paired with negatively framed messages ($M = 3.60$, SD = 1.23; $t(52) = -0.20$, $p = 0.14$).

Results

To test Hypothesis 1 that positively framed messages motivate older adults more than negatively framed messages to participate in physical activities, we performed a paired *t*-test comparing motivation scores for the two types of messages. For all analyses, we used one-sided tests as we had directional hypotheses. Results revealed a statistical trend in the expected direction; positively framed messages ($M = 2.43 \pm 0.82$) were rated as being more motivating than negatively framed messages ($M = 2.28 \pm 0.82$; $t(52) = 1.30$, $p = 0.099$, $d = 0.36$; see Fig. 1). Follow-up analyses of motivation per film showed higher or comparable scores for positively framed messages for all programmes except yoga (Gaming: $M_{\text{positive}} = 2.14 \pm 0.96$; $M_{\text{negative}} = 2.15 \pm 1.17$; Tai Chi: $M_{\text{positive}} = 2.46 \pm 1.10$; $M_{\text{negative}} = 2.22 \pm 1.16$; Nordic Walking: $M_{\text{positive}} = 2.79 \pm 1.09$; $M_{\text{negative}} = 2.29 \pm 0.95$; Senior Fit: $M_{\text{positive}} = 2.39 \pm 1.14$; $M_{\text{negative}} = 2.11 \pm 1.17$; Zumba: $M_{\text{positive}} = 2.78 \pm 0.97$; $M_{\text{negative}} = 2.49 \pm 1.10$; Yoga: $M_{\text{positive}} = 1.95 \pm 1.17$; $M_{\text{negative}} = 2.43 \pm 1.35$; see Table 1). When we excluded the Yoga programme from the analysis, the difference between positively framed ($M = 2.47 \pm 0.12$) and negatively framed messages ($M = 2.24 \pm 0.78$) in motivating participants for physical activity was significant, $t(52) = 1.70$, $p = 0.047$, $d = 0.47$. We also re-ran analyses as Repeated-Measures ANOVAs to control for gender, health, and cognitive performance; the pattern of results remained the same.

To test Hypothesis 2 that older adults remember positively framed physical activity messages better than negatively framed messages, we conducted a paired *t*-test in which we compared the proportion of correctly recalled programmes paired with a positively framed message to the proportion of correctly recalled programmes paired with a negatively framed message. The analysis revealed no significant difference by valence ($M_{\text{positive}} = 0.57 \pm 0.35$; $M_{\text{negative}} = 0.56 \pm 0.31$; $t(52) = 0.24$, $p = 0.405$; see Table 2). With regard to recognition, participants correctly recognized a greater number of activities paired with positively framed ($M = 0.78 \pm 0.25$) than negatively framed messages ($M = 0.42 \pm 0.29$), $t(51) = 6.72$, $p < 0.001$, $d = 1.88$; see Table 2; Fig. 1). For programmes paired with positively framed messages, recognition accuracy ($M = 78.21 \pm 24.60$ %) was above chance ($t(51) = 8.27$, $p < 0.001$, $d = 2.32$). In contrast, for programmes paired with negatively framed messages ($M = 41.67 \pm 29.43$ %), recognition accuracy was worse than chance ($t(51) = -2.04$, $p = 0.046$, $d = -0.57$). Because participants had been introduced to all programmes with only the message framing varying and were simply asked to indicate if they had seen the positively framed or the negatively framed

Table 1 Motivation scores by experimental condition

Motivation	Positive framing		Negative framing	
	M	SD	*M*	SD
Average across programmes	2.43	0.82	2.28	0.82
Average across programmes without yoga	2.47	0.12	2.24	0.78
Gaming	2.14	0.96	2.15	1.17
Tai Chi	2.46	1.10	2.22	1.16
Nordic Walking	2.79	1.09	2.29	0.95
Senior fit	2.39	1.14	2.11	1.17
Zumba	2.78	0.97	2.49	1.10
Yoga	1.95	1.17	2.43	1.35

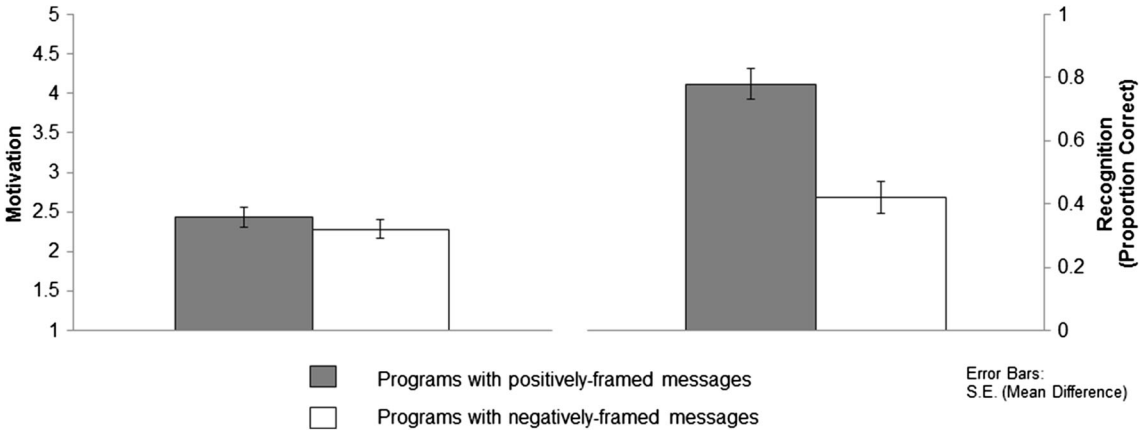

Fig. 1 Results from paired *t*-tests comparing motivation scores and recognition memory for six film clips paired with positively framed and negatively framed messages. Motivation ratings were given on a 5-point Likert scale ranging from 1 to 5. Recognition scores could range from 0 to 1

Table 2 Memory by experimental condition (proportion correct)

Type of memory	Positive framing		Negative framing	
	M	SD	*M*	SD
Recall	0.57	0.35	0.56	0.31
Recognition	0.78	0.25	0.42	0.29

message for each programme, the recognition results suggested a systematic bias to reframe negative messages as positive. Follow-up analyses for free recall and recognition excluding the yoga programme revealed the same pattern as did Repeated-Measures ANOVAs, in which we added health and cognitive performance as covariates.

Discussion

Given the many documented benefits of physical activity, older adults are frequently exposed to messages recommending active lifestyles. Recently, Notthoff and Carstensen (2014) showed that—in line with the positivity effect—positively framed messages promoted walking in older adults better than negatively framed messages. In this study, we examined the role of memory and motivation as mechanisms that presumably underlie the greater effectiveness of positively framed compared to negatively framed messages about physical activities. Additionally, we tested whether such motivational messages can promote motivation and memory for activities besides walking.

Consistent with Hypothesis 1, across five of six physical activity programmes, older adults tended to perceive positively framed messages as more motivating than negatively framed messages. Specifically, older adults found programmes introduced by accentuating the benefits gained from the activity, rather than the risks associated from not pursuing it relatively more attractive and useful, and expressed a relatively stronger intention to participate. This supports the notion that framed health messages may operate by differentially influencing motivation and is in line with prior research showing that older adults rated positively framed health information pamphlets more favourably than negatively framed ones (Shamaskin et al. 2010). Our finding held across physical activities with the

exception of Yoga. In hindsight, we noted that this particular film was recorded with little light and sound in order to create the calm atmosphere typical for Yoga. This may have made it harder for participants to see the film. Additionally, participants could have perceived yoga as less positive than the other programmes, for which films showed people exercising enthusiastically to upbeat music or in sunny outdoor scenery.

Our second hypothesis regarding memory was partially supported. Older adults recognized pairs of physical activity programmes and positively framed messages better than pairs of physical activity programmes and negatively framed messages. This was due to the fact that older adults misremembered negatively framed messages to be positively framed, which replicates prior findings (Shamaskin et al. 2010). However, presenting both the positively framed and negatively framed version of each message in the recognition test and asking participants to indicate which one they had seen earlier—a procedure that we adopted from Shamaskin et al. (2010)—might not be the optimal way to test which type of message best promotes recognition of the physical activity programmes. Instead, future studies could rely on distractor messages that were not previously presented. That way, it would become clear whether participants actually remember the programmes, rather than simply remembering whether a programme was paired with a positively framed or a negatively framed message.

When asked to freely recall activity programmes, older adults did not remember programmes paired with positively framed messages better than those paired with negatively framed messages. On the whole, participants recalled only about a third of the programmes that had been introduced to them. It is possible that they had difficulty remembering the names of potentially unfamiliar activity programmes, but did remember the overall message that physical activity has health benefits, and therefore endorsed the positive framing condition; this idea needs to be tested in the future. The divergent findings for recognition and recall are consistent with some earlier studies (e.g. Kwon et al. 2009) though not others (e.g. Charles et al. 2003). A possible reason is that recall was tested immediately after message delivery, followed by recognition memory. It has previously been argued that the pursuit of emotional goals, which presumably drives the positivity effect, needs time to take effect (Isaacowitz et al. 2009). Future research should add a filler task before memory testing.

Overall, the present study suggests that motivation and memory may be viable mechanisms underlying the differential effectiveness of positively framed and negatively framed messages for promoting physical activity in older adults. In a future study, engagement in the advocated health behaviours should be assessed objectively to examine whether the link between the mechanisms motivation and memory and the behaviour physical activity holds, as hypothesized. Additionally, to truly examine whether the positivity effect is at play here, a future study should compare older and younger adults' memory for, and motivation and behaviour resulting from positively framed versus negatively framed health messages. It will also be useful to replicate results in a larger sample and to pay people for participation, rather than to give out vouchers for activity programmes as a reward. Although people who volunteer for studies on physical activity most likely have an interest in the topic, providing coupons for the activity programmes that were featured in the study may have led to the selection of participants who were particularly positively motivated for physical activity, and thus, were responding especially well to positively framed messages.

In conclusion, the current findings lend further support to the idea that considering age-related changes in motivation and information processing is useful for designing effective, inexpensive health interventions for older adults that target a range of physical activities.

Acknowledgments We gratefully acknowledge the many research assistants who assisted with data collection.

Appendix 1: The messages (Translated from Dutch)

Gaming: Positive

Gaming is a physical activity programme in which you can train your balance and coordination using a computer. Your coordination and balance will improve. Better balance and coordination will enhance your concentration and sense of stability. Your walking will become safer and steadier.

Gaming: Negative

Gaming is a physical activity programme in which you can train your balance and coordination using a computer. It prevents your coordination and balance from diminishing. Declining coordination and balance will make you feel distracted more quickly and your walking will be less stable. This will increase your risk of falling and breaking your bones.

Tai Chi: Positive

Tai Chi is a physical activity programme in which you make fluent movements to music. It is focused on improving your body awareness. By increasing your body

awareness, you will become more relaxed and flexible. You will perform daily tasks more easily.

Tai Chi: Negative

Tai Chi is a physical activity programme in which you make fluent movements to music. It is focused on body awareness. Not listening to our bodies carefully will lead to increased stress and stiffness. It will be more difficult to perform daily tasks.

Nordic Walking: Positive

Nordic Walking is a physical activity programme in which you walk with walking poles. You will increase your physical fitness. Better physical fitness will make you feel in shape and your heart will become stronger and will beat more forcefully.

Nordic Walking: Negative

Nordic Walking is a physical activity programme in which you walk with walking poles. You prevent that your physical fitness declines. Decreased physical fitness will make you feel lethargic, and you run the risk of experiencing a heart attack or stroke.

Senior Fit: Positive

Senior Fit is a physical activity programme that focuses on training your muscle strength. Your muscle strength will increase. Enhanced muscle strength will make you feel stronger, and you will be able to perform physically demanding tasks better and for a longer time.

Senior Fit: Negative

Senior Fit is a physical activity programme that focuses on training your muscle strength. You prevent that your muscle strength diminishes. Decreased muscle strength will make you feel weaker, and you will find it harder to perform physically demanding tasks and will have to stop sooner.

Zumba: Positive

Zumba is a physical activity programme in which you dance to Latin-American music. Your vitality will increase. By enhancing your vitality, you will have a stronger desire to be socially active and be more emotionally stable.

Zumba: Negative

Zumba is a physical activity programme in which you dance to Latin-American music. You prevent that your vitality diminishes. Decreased vitality will result in tiredness and lethargy. You will withdraw more quickly and be more emotional unstable.

Yoga: Positive

Yoga is a relaxation programme that is focused on slow movements to the rhythm of your breath. You will achieve better relaxation. Enhanced relaxation will result in a more relaxed attitude, and you will feel happier. Your sleep quality will increase.

Yoga: Negative

Yoga is a relaxation programme that is focused on slow movements to the rhythm of your breath. This will lead to less body tension. High body tension leads to stress and makes you feel unhappy. Your sleep can be disturbed.

References

Ardila A (2007) Normal ageing increases cognitive heterogeneity: analysis of dispersion in WAIS-III scores across age. Arch Clin Neuropsychol 22:1003–1011. doi:10.1016/j.acn.2007.08.004

Bandura A (1997) Self-efficacy: the exercise of control. W H Freeman/Times Books/Henry Holt & Co, New York

Carstensen LL, Isaacowitz DM, Charles ST (1999) Taking time seriously: a theory of socioemotional selectivity. Am Psychol 54:165–181. doi:10.1037/0003-066X.54.3.165

Charles ST, Mather M, Carstensen LL (2003) Ageing and emotional memory: the forgettable nature of negative images for older adults. J Exp Psychol Gen 132:310–324. doi:10.1037/0096-3445.132.2.310

Covey J (2014) The role of dispositional factors in moderating message framing effects. Health Psychol 33:52–65. doi:10.1037/a0029305

Eccles W (2002) Motivational beliefs, values, and goals. Annu Rev Psychol 53:109–132. doi:10.1146/annurev.psych.53.100901.135153

European Commission (2014). Special eurobarometer 412: sport and physical activity. Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_412_en.pdf

Hamer M, Lavoie KL, Bacon SL (2013) Taking up physical activity in later life and healthy ageing: the English longitudinal study of ageing. Br J Sports Med 48:239–243. doi:10.1136/bjsports-2013-092993

Hertzog C, Kramer AF, Wilson RS, Lindenberger U (2008) Enrichment effects on adult cognitive development: can the functional capacity of older adults be preserved and enhanced? Psychol Sci Public Interest 9:1–65. doi:10.1111/j.1539-6053.2009.01034.x

Isaacowitz DM, Allard ES, Murphy NA, Schlangel M (2009) The time course of age-related preferences toward positive and negative stimuli. J Gerontol Ser B: Psychol Sci 64(B):188–192. doi:10.1093/geronb/gbn036

Kwon Y, Scheibe S, Samanez-Larkin GR, Tsai JL, Carstensen LL (2009) Replicating the positivity effect in picture memory in Koreans: evidence for cross-cultural generalizability. Psychol Aging 24:748–754. doi:10.1037/a0016054

Löckenhoff CE, Carstensen LL (2007) Ageing, emotion, and health-related decision strategies: motivational manipulations can reduce age differences. Psychol Aging 22:134–146. doi:10.1037/0882-7974.22.1.134

Mann T, Sherman D, Updegraff J (2004) Dispositional motivations and message framing: a test of the congruency hypothesis in college students. Health Psychol 23:330–334. doi:10.1037/0278-6133.23.3.330

Notthoff N, Carstensen LL (2014) Positive messaging promotes walking in older adults. Psychol Aging 29:329–341. doi:10.1037/a0036748

O'Donovan G, Blazevich AJ, Boreham C, Cooper AR, Crank H, Ekelund U, Fox KR, Gately P, Giles-Corti B, Gill JM, Hamer M, McDermott I, Murphy M, Reilly JJ, Saxtion JM, Stamatakis E (2010) The ABC of physical activity for health: a consensus statement from the British Association of Sport and Exercise Sciences. J Sports Sci 28:573–591. doi:10.1080/02640411003671212

Reed AE, Carstensen LL (2012) The theory behind the age-related positivity effect. Front Psychol 3:339. doi:10.3389/fpsyg.2012.00339

Rothman AJ, Salovey P (1997) Shaping perceptions to motivate healthy behavior: the role of message framing. Psychol Bull 121:3–19. doi:10.1037/0033-2909.121.1.3

Shamaskin AM, Mikels JA, Reed AE (2010) Getting the message across: age differences in the positive and negative framing of health care messages. Psychol Aging 25:746–751. doi:10.1037/a0018431

Sherman DK, Mann T, Updegraff JA (2006) Approach/avoidance motivation, message framing, and health behavior: understanding the congruency effect. Motiv Emotion 30:165–169. doi:10.1007/s11031-006-9001-5

Tombaugh TN, Kozak J, Rees L (1999) Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. Archiv Clin Neuropsychol 14:167–177. doi:10.1016/S0887-6177(97)00095-4

Visser M, Pluijm SM, Stel VS, Bosscher RJ, Deeg DJ (2002) Physical activity as a determinant of change in mobility performance: the Longitudinal Ageing Study Amsterdam. J Am Geriatr Soc 50:1774–1781. doi:10.1046/j.1532-5415.2002.50504.x

Ware J Jr, Kosinski M, Keller SD (1996) A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. Med Care 34:220–233. doi:10.1097/00005650-199603000-00003

Withall J, Stathi A, Davis M, Coulson J, Thompson JL, Fox KR (2014) Objective physical activity and sedentary time and associations with subjective well-being in adults aged 70 and over. Int J Environ Res Public Health 11:643–656. doi:10.3390/ijerph110100643