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Functional Ability in Everyday Life: Are Associations with an Engaged Lifestyle Mediated by Working Memory?

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Abstract

Objectives: An engaged lifestyle has been linked to measures of functional ability in everyday life. However, the underlying mechanism of this link is still understudied. We propose working memory as a potential mediator of this relation. *Method:* Modelling data of 158 older adults with a latent-variables approach, we examined whether working memory mediated the relation between an engaged lifestyle, that is, intellectual, social and physical activities, and functional ability, that is, self-reported everyday failures and test-based everyday performance. *Results:* Working memory was found to fully mediate the relation between gaming activities and test-based everyday performance. Further, we found a negative association between sports activities and self-reported everyday failures not mediated through working memory, indicating that individuals who reported high levels of sports activities reported fewer everyday cognitive failures. All other lifestyle activities were, however, neither directly nor indirectly associated with functional ability. *Discussion:* Working memory is one pathway by which gaming activities are related to test-based measures of functional ability in everyday life. Given the overlapping cognitive demands of working memory, gaming activities, and the test-based measure of functional ability, the findings suggest that while an engaged lifestyle can benefit functional ability, those benefits may be limited to highly similar domains.

Keywords: Mediation analysis, successful aging, executive function, life events and contexts

Functional Ability in Everyday Life: Are Associations with an Engaged Lifestyle Mediated by Working Memory?

The World Health Organization (WHO, 2015) in its first World Report on Ageing and Health proposes a theoretical framework on healthy aging that reflects an explicit process- and context-centered view. In this framework, healthy aging is defined as fostering and sustaining functional ability in everyday life to support well-being in older age. To better understand healthy aging and its antecedents, the WHO suggests focusing on both the level of symptoms and on functional ability, that is, the ability to do what the individual values, such as being mobile, building and maintaining relationships, and lifelong learning. Functional ability is composed of physical and mental characteristics of individuals and their environment as well as the interactions thereof. Thus, to understand how healthy aging can be promoted, emphasis should be put more strongly on correlates and antecedents of functional ability, such as an engaged lifestyle, and the mechanisms underlying this relationship. In this study, we investigated whether working memory (WM) mediates the benefits of an engaged lifestyle on everyday functional ability.

Numerous studies have established the relation between an engaged lifestyle and functional ability (e.g., Cockburn & Smith, 1991; Kalisch et al., 2011; Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010; Lennartsson & Silverstein, 2001; Maier & Klumb, 2005). It has been proposed that an engaged lifestyle provides compensatory scaffolding (Reuter-Lorenz & Park, 2014) and builds cognitive reserve (Stern, 2009) by promoting positive cognitive and neural plasticity. In line with these propositions, an extensive amount of research has identified three clusters of lifestyle activities, namely intellectual, social, and physical activities (Harada, Natelson Love, & Triebel, 2013; Hertzog, Kramer, Wilson, & Lindenberger, 2009), that are related to cognitive functioning. These studies found that lifestyle activities are positively related to both cognitive functioning, its stabilization and enhancement, and negatively to the incidence of mild cognitive impairment and dementia (see Hertzog et al., 2009 for an overview). In addition, bi-directional effects between intellectual and physical activities, and cognitive functioning have been reported (e.g., Daly, McMinn, & Allan, 2015; Small, Dixon, McArdle, & Grimm, 2012). Most research in this area is based on correlational evidence and, thus, reverse causality cannot be ruled out. There is, however, experimental evidence from intervention studies providing support for the beneficial effects of an engaged lifestyle on cognitive functioning (e.g., Stine-Morrow, Parisi, Morrow, & Park, 2008; Tennstedt & Unverzagt, 2013).

Moreover, cognitive functioning has been proposed to be one of the most important antecedents of functional ability (e.g., Diehl, 1998; Schaie, Boron, & Willis, 2005). Fluid cognitive abilities, including reasoning, perceptual speed, and WM, have been shown to strongly correlate with both self-reported and test-based measures of functional ability (Cockburn & Smith, 1991; Diehl, Willis, & Schaie, 1995), accounting for up to more than half of the variance in functional ability (e.g., Willis, Jay, Diehl, & Marsiske, 1992), with WM being one of the strongest correlates (Borella et al., 2017; Lewis & Miller, 2007).

However, as yet, no study has directly tested whether cognitive functioning mediates the association between activities of an engaged lifestyle and functional ability. The present study fills this gap by investigating WM as one pathway by which an engaged lifestyle is related to functional ability. WM has been defined as a capacity-limited cognitive ability that provides access to representations that are required for performing complex cognitive tasks (Cowan, 2017). WM is also related to cognitive real-world tasks in social (e.g., language and listening comprehension, storytelling) and intellectual contexts (e.g., logic learning, taking lecture notes; see Feldman Barrett, Tugade, & Engle, 2004 for an overview). Further, WM is a highly reliable construct (Conway, Kane, Bunting, Hambrick, Wilhelm & Engle, 2005), which is strongly correlated with other higher-order fluid cognitive abilities such as intelligence, inhibition, processing speed and shifting (e.g., Kyllonen & Christal, 1990; Miyake & Shah, 1999; Schmiedek, Oberauer, Wilhelm, Süss & Wittmann, 2007) prone to age-related cognitive decline (e.g., Craik & Bialystok, 2006; Salthouse, 1996). It therefore constitutes an excellent proxy for general fluid cognitive abilities and candidate mediator for explaining the well-established but yet poorly understood relation between an engaged lifestyle and functional ability.

In light of previous work showing evidence for bilateral relations between how individuals spend their daily lives, their cognitive functioning and how well they function in everyday life, we examined the three-fold associations that fit well with basic tenets of the WHO framework on healthy aging. We aimed to (a) identify modifiable correlates, that is, intellectual, social, and physical activities of self-reported and test-based functional ability, and to (b) examine WM as one potential mediator of these associations. To test our hypotheses, we conducted latent mediation analyses using structural equation modeling (SEM). One advantage of SEM is that it separates true interindividual difference variance from variance caused by measurement error.

Methods

The data are the reanalyzed pretest data from a previously reported cognitive training study (for detailed methods, see Guye & von Bastian, 2017), in which we determined the sample size by aiming at recruiting at least three times as many participants than previous studies in this research area.

Participants

Participants were 158 older adults (79 females) aged 64 to 80 years (*M* = 70.41, *SD* = 3.62) who were recruited through our participant pool, during lectures of the Senior University of Zurich, flyers, online announcements, and word-of-mouth. They were paid

CHF 150 (approx. USD 150) for participating in the training intervention. Exclusion criteria were psychiatric or neurological disorders, psychotropic drug use, severe motor, hearing, or vision impairments potentially impacting cognitive functioning, color blindness (Ishihara, 1917), depression (GDS; Sheikh & Yesavage, 1986; cut-off = 4; *M* = 0.64, *SD* = 0.95), and cognitive impairment (MMSE; Folstein, Folstein, & McHugh, 1975; cut-off = 26; *M* = 29.23, *SD* = 0.85). Participants had to be retired, German speaking, and to own a computer with Internet connection. They were fairly well educated with a median education level of 4, which corresponds to the Swiss Matura degree and is comparable to the Higher Education Entrance Qualification in the US (*MAD* = 2.97; range from 0 = *no formal education* to 7 = *doctorate*).

Measures

Engaged lifestyle. Intellectual, social, and physical activities were assessed using an adapted version of the adult leisure activity questionnaire (Jopp & Hertzog, 2010), which included 54 activities. Participants indicated how frequently they partook in each activity during the last two weeks on a 6-point Likert scale (1 = *never*, 2 = *occasionally*, 3 = *once a month*, 4 = *once a week*, 5 = *multiple times per week*, 6 = *daily*). These activities belonged to the 11 activity domains established by Jopp and Hertzog (2010), seven of which were used in this analysis: experiential, developmental, physical, social-private, social-public, and gaming and technological activities. The remaining four activity domains were not included in this analysis as they did not fit the intellectual, social or physical activity cluster.

Intellectual activities. We assessed the experiential *("business not related to job", "collect stamps", "read for leisure", "read newspaper", "write letters",* and *"craft (e.g., sewing, knitting, crafts);* Cronbach's α = 0.34*)",* the developmental *("garden indoor or outdoor", "attend movies", "read books as part of job", "attend public lecture", "course at university", "creative writing (e.g., poems or books)", "go to library", "study foreign* *language",* and *"theatre, concerts, and exhibitions";* Cronbach's α = 0.47*),* the gaming *("play knowledge games", "play board games", "play puzzles", "do cross-word puzzles",* and *"play card games"*; Cronbach's α = 0.56*),* and the technological activity domain *("engage in photography", "play an instrument", "use computer software", "use electronic calculator", "arithmetic calculations",* and *"prepare own income tax"*; Cronbach's α = 0.53*).*

Social activities. We assessed the social-private ("*go out with friends",* "*visit friends or relatives",* "*attend parties (e.g., birthday"),* "*talk to friends or family on the phone",* "*give dinner for friends or family",* and "*eat out at restaurant"*; Cronbach's α = 0.59) and the social-public activity domain ("*engaged in political activities",* "*give public talk",* "*attend club meetings",* "*attend organized social events",* and "*volunteer"*; Cronbach's α = 0.65).

Physical activities. We assessed the sports activities domain ("*weight lift and strength",* "*aerobics",* "*flexibility (e.g., stretching, yoga, tai chi)",* "*outdoor (e.g., sail, fish, walk, skiing)",* "*exercise (jog, bike, swim)",* and "*dance"*; Cronbach's α = 0.51).

Functional ability. Functional ability was assessed using self-report and test-based measures to identify differential relations to lifestyle activities and thus derive tentative recommendations for specific aspects of functional ability. Whereas self-reported measures reflect an individual's perceived functional ability in everyday life, test-based measures reflect actual performance on real life tasks.

Self-reported everyday failures. The German version of the Cognitive Failure Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982; Klumb, 1995) is a self-report measure on 32 possible failures (Cronbach's α = .92) in perception (e.g., "*Do you fail to see what you want in a supermarket (although it's there)?*"), memory (e.g., "*Do you find you forget appointments?*"), and motor function (e.g., "*Do you drop things?*"). Participants had to indicate how often one of these failures occurred during the last weeks on a 5-point

Likert scale (0 = *never*, 1 = *very rarely*, 2 = *occasionally*, 3 = *quite often*, 4 = *very often*). The questionnaire was computer-based and the mean score was used as dependent variable.

Test-based everyday performance. The Everyday Problems Test (EPT; Willis & Marsiske, 1993) is an test-based measure to assess individuals' ability to solve tasks encountered in everyday life. Participants had to solve 15 everyday tasks (Cronbach's α = .75) that we translated to German and adapted to a Swiss context, each consisting of two problems associated with the everyday tasks on printed material. To indicate their response, participants had to choose the correct out of four possible answers. The number of correctly solved problems within 45 minutes was used as dependent variable.

Working memory. WM was measured with two tasks assessing storage and processing ability (complex span and Brown-Peterson), two tasks assessing binding ability, and two tasks assessing memory updating ability (for reliabilities see Guye & von Bastian, 2017).

Storage and processing. In the complex span task, participants had to memorize a series of positions of red squares presented in a 5 x 5 grid. We presented six trials per set size (i.e., 2-4 memoranda). Each trial of the series was interleaved by a distractor task, in which vertically or horizontally oriented L-shaped figures had to be rated according to their orientation (von Bastian & Eschen, 2016). In the Brown-Peterson task, participants had to memorize a series of Gabor patches. We presented four trials per set size (i.e., 2-4). The memorization phase was followed by a distractor task in which the length of a horizontally oriented bar had to be compared to a gap between two points (Brown, 1958; Peterson & Peterson, 1959). Stimuli were presented for 1000 ms and the distractor task lasted maximally 3000 ms. Storage accuracy was used as the dependent measure.

Binding. We used two versions of the binding task (adapted from Oberauer, 2005). In the triangles task, participants had to memorize a series of colored triangles at their locations in a 4 x 4 grid. In the shape task, participants had to memorize a series of colored shapes at their locations in a 1 x 4 grid. We presented six trials per set size in the triangles task and eight trials per set size in the shape task, with the set sizes ranging between 2 and 4 memoranda. After memorization, positive probes (i.e., memorandum at correct location, 50% of probes) or negative probes (i.e., memorandum at wrong location or extra-list item, each 25% of probes) were presented. We used *d*' (i.e., the difference between *z*-transformed hits and false alarms) as the dependent variable.

Memory updating. In the location-updating task (adapted from De Simoni & von Bastian, 2018), participants had to first memorize the locations of a set of circles in a 4 x 4 grid and then to update their positions by mentally shifting them to the adjacent cell based on the orientation of an arrow. We presented six trials per set size (i.e., 2-4 memoranda). In the orientation-updating task, participants had to memorize the orientation of arrows pointing in 1 out of 8 directions. Then, they were required to update the arrow's orientation by rotating them according to a presented arrow and indicate the new direction. We presented eight trials per set size (i.e., 2-4). Stimuli were presented for 500 ms and each updating step lasted 500 ms. Accuracy was used as the dependent measure.

Results

Data and analyses scripts are available on the Open Science Framework (OSF; https://osf.io/2jbpx). All analyses were conducted in R (version 3.2.3; R Core Team, 2016). Latent mediation models were run with the lavaan package (0.5-23.1097; Rosseel, 2012). Descriptive statistics for the measures of an engaged lifestyle, WM, and functional ability are listed in Table 1 (for correlations see Table S1).

First, we evaluated the measurement model of the latent WM variable using confirmatory factor analysis. Second, we conducted six models to test the relation between lifestyle activities (intellectual, social, or physical) and functional ability (self-reported or test-based), and whether these associations were mediated through WM. Age and education were included as covariates; the results remained qualitatively the same when excluding those variables though. All variables were *z*-standardized prior to the analyses.

Model fit was assessed using a combination of goodness of fit indices, including the Chi-Square goodness of fit test (χ^2), standardized root-mean-square residual (SRMR), root-mean-squared error of approximation (RMSEA) including its 90% credible interval (CI), and Comparative Fit Index (CFI). χ^2 values between 0 and 2*df* (and $p \geq .05$), SRMR ≤ .05, RMSEA ≤ .05, and CFI ≥ 0.97 are considered good fit, χ^2 values between 2*df* and 3*df* (and $p \leq .05$), SRMR ≤ .10, RMSEA ≤ .08, and CFI ≥ 0.95 are considered acceptable fit (Hu & Bentler, 1999; Schermelleh-Engel, Moosbrugger, & Müller, 2003). To obtain 95% bias corrected confidence intervals (95% CI), we used the bootstrap estimation approach (10,000 samples) implemented in lavaan.

Insert Table 1 here

Measurement Model of Working Memory

The six WM tasks were specified to load on one latent WM factor, which yielded an acceptable fit $\chi^2(9) = 16.18$, $p = .063$, SRMR = .04, RMSEA = .07 [.00 - .13], CFI = .97. The standardized factor loadings were all significant (all *p*s < .001; complex span = .60, Brown-Peterson = .62, binding triangles = .66, binding shapes = .36, memory updating locations = .64, memory updating arrows = .73)

Latent Mediation Model

Six latent mediation models of WM as the mediator were tested, one for each combination of lifestyle activity indicators (i.e., intellectual, social, and physical) and functional ability measures (i.e., self-reported everyday failures and test-based everyday performance). Figure 1 depicts an overview of the results. All models yielded an acceptable or good fit (see Table S2).

Insert Figure 1 here

Self-reported everyday failures. Table S3 lists the detailed results for the models including self-reported everyday failures.

Intellectual activities. We found that gaming activities were positively related to WM, indicating that individuals who reported more gaming activities also showed better WM performance (a_3 = 0.17, 95% CI [0.06 – 0.28], *z* = 3.12, *p* = .002). Also, age (*b* = -0.03, 95% CI [-0.07 – 0.00], *z* = 1.97, *p* = .049) and education (*b* = .13, 95% CI [0.06 – 0.19], *z* = 3.90, *p* < .001) were related to WM, but no other effects – including the mediation – were significant.

Social activities. Education (*b* = .11, 95% CI [0.05 – 0.16], *z* = 3.55, *p* <.001) but not age (*b* = -0.03, 95% CI [-0.06 – -0.00], *z* = 1.86, *p* = .064) was related to WM. Neither the association between social activities and self-reported everyday failures nor the mediation through WM or any other effects were significant.

Physical activities. We found a negative relation between sports activities and self-reported everyday failures (*c* = -0.16, 95% CI [-0.30 – -0.02], *z* = 2.26, *p* = .024), indicating that individuals who reported high levels of sports activities reported fewer cognitive failures in everyday life. However, WM was neither associated with sports activities (*a* = 0.00, 95% CI [-0.10 – 0.11], *z* = 0.07, *p* = .943) nor self-reported everyday failures (*b* = -0.19, 95% CI [-0.56 – 0.10], *z* = 1.15, *p* = .251). Consequently, the indirect effect was not significant (*a*b* = -0.00, 95% CI [-0.03 – 0.03], *z* = 0.05, *p* = .957) and the direct effect remained significant after including WM in the model (*c*' = -0.16, 95% CI [-0.30 – -0.01], *z* = 2.18, *p* = .029). Again, education (*b* = .11, 95% CI [0.05 – 0.17], z = 3.70, *p* < .001), but not age (*b* = -0.03, 95% CI [-0.06 – 0.00], z = 1.81, p = .071) was related to WM. No other effects were significant.

Test-based everyday performance. Table S4 lists the detailed results for the models including test-based everyday performance.

Intellectual activities. As for the models on self-reported everyday failures, we found that gaming activities were positively related to WM (a_3 = 0.17, 95% CI [0.06 – 0.28], z = 3.09, p = .002). Moreover, WM was positively related to test-based everyday performance (b = 0.65, 95% CI [0.40 – 1.01], z = 4.19, p < .001). This suggests that individuals who reported more gaming activities exhibited better WM and that individuals with better WM showed better test-based everyday performance. In addition, we found a total effect of gaming activities on test-based everyday performance, c_3 = 0.18, 95% CI [0.03 – 0.33], z = 2.27, p = .023. Notably, this effect was no longer significant when including WM in the model (c'_3 = 0.06, 95% CI [-0.07 – 0.21], z = 0.88, p = .379), indicating that WM fully mediated the relationship. Indeed, the indirect effect of gaming activities on test-based everyday performance through WM was significant, a_3*b = 0.11, 95% CI [0.04 – 0.19], z = 2.83, p = .005. Age (b = -0.03, 95% CI [-.07 – -.00], z = 2.01, p = .044) and education (b = 0.13, 95% CI [0.06 – 0.19], z = 3.89, p < .001) were related to WM. No other effects were significant.

Social activities. We found no significant relation between social activities and WM, but WM was again positively related to test-based everyday performance (b = 0.71, 95% CI [0.44 – 1.10], z = 4.29, p < .001), indicating that individuals with better WM showed better test-based everyday performance. In this model, education (b = .11, CI [95%] = 0.05 – 0.17, z = 3.53, p < .001) was again related to WM, but not age (b = -0.03, CI [95%] = -0.06 – -0.00, z = 1.86, p = .063). No further effects were significant.

Physical activities. As with social activities, there was no evidence for a relation between sports activities and WM, but we again found a positive relation between WM and test-based everyday performance (*b* = 0.73, 95% CI [0.46 – 1.12], *z* = 4.29, *p* < .001), indicating that individuals with better WM showed better test-based everyday performance. Again, education (*b* = .11, 95% CI [0.05 – 0.17], *z* = 3.80, *p* < .001), but not age (*b* = -0.03, 95% CI [-0.06 – 0.00], *z* = 1.87, *p* = .062) were related to WM. No other effects were significant.

Discussion

To the best of our knowledge, this study is the first to extend previous research on the effect of an engaged lifestyle, assessed via different activities, on functional ability, whilst considering WM as a potential mediator. To test our hypothesis, we used multiple indicators for each construct, conceptualizing an engaged lifestyle as intellectual, social, and physical activities, functional ability as self-reported everyday failures and test-based everyday performance, and assessing WM with multiple tasks.

Engaged Lifestyle and Functional Ability

We found evidence that certain lifestyle activities were associated with functional ability. More specifically, we found that sports activities were associated with self-reported everyday failures, and that gaming activities were associated with test-based everyday performance. This extends previous research which has primarily focused on the relationship between lifestyle activities and cognitive functioning (e.g., Herzog et al., 2009). Our findings indicate that modifiable sports and certain types of intellectual everyday life activities are associated with how older adults perceive their functional ability in daily life and how well they perform on everyday life tasks. This is in line with the resource-focused tenets of the WHO framework on healthy aging emphasizing the importance of identifying modifiable lifestyle characteristics to maintain or enhance functional ability in older age, which ultimately also influences judgements about the value of life (e.g., Lawton et al., 1999).

Surprisingly, however, all other lifestyle activities (i.e., experiential, developmental, technological, public and private social activities) were neither directly nor indirectly associated with functional ability. Hence, the effects found were not driven by an engaged lifestyle in general but were specific to certain aspects within the physical and intellectual activity domains. This pattern warrants further scrutiny to better understand the pathways in which engagement in, for instance, sports activities are related to fewer reports about one's everyday failures. Further, our measure for sports activities did not differentiate between different sports such as solitary and group sports with varying degrees of complexity (dance choreography vs. strength training). Future research exploring the differential associations with self-reported measures of functional ability would be valuable to identify how sports activities are related to functional ability over and above objective physical fitness. For example, given the importance of physical fitness to living an independent life, older adults who are able to engage in sports activities may benefit from feelings of higher motor and physical functional ability when facing everyday life tasks and challenges. In contrast, gaming activities were related only to the test-based measure of functional ability and do not seem to be associated with subjective feelings of functional ability (see below for a more detailed discussion).

Taken together, our results indicate that only particular activities from the intellectual domain (i.e., gaming activities) and sports activities may facilitate functional ability, and only specifically on the level of self-reports or test-based performance. This is consistent with the core ideas of the WHO framework on healthy aging that self-reported and test-based measures of functional ability represent distinct aspects of an individuals' everyday functioning and, thus, should be treated as such. These findings have also important implications for the development of interventions aiming at improving functional ability. On the one hand, identifying the types of lifestyle activities that benefit functional ability may inform intervention research to guide the development of intervention programs. On the other hand, intervention studies can determine whether those particular activities causally affect functional ability. Eventually, these specific activities can then be fit with a person's daily routines and other personal goals when recommending an engaged lifestyle or lifestyle changes.

Working Memory as Mediator

Our second goal was to examine WM as a potential mediator of the lifestyle-functional ability relationship. We found that gaming activities were associated with WM, corroborating earlier findings from previous cross-sectional research showing a positive relationship between gaming activities and cognition (e.g., Jopp & Hertzog, 2010). This finding is also consistent with evidence from longitudinal research suggesting that gaming activities and game-like cognitive training are associated with increased cognitive performance (e.g., Basak, Boot, Voss & Kramer, 2008), less cognitive decline five years later (e.g., Ghisletta, Lövdén, & Bickel, 2006) and reduced risk of dementia (e.g., Edwards, Xu, Clark, Guey, Ross & Unverzagt, 2017; Hughes, Chang, Vander Bilt, & Ganguli, 2010). The association between gaming activities and WM has been suggested to be due to the comparatively high cognitive challenge of gaming activities relative to other leisure activities, implying that the level of complexity of a given activity might be one critical moderator for the relationship between an engaged lifestyle and cognitive functioning (Ghisletta et al., 2006). Further, our results showed that WM was associated with test-based, but not self-reported, functional ability. The relation between the EPT, the measure used in this study to assess test-based functional ability, and WM, may be explained by the similarities between the task demands. On the surface level, the EPT requires active storage and manipulation of information as well as the integration of information to solve the everyday-life problems posed, processes central to WM (Oberauer, Süß, Wilhelm, &

Wittmann, 2003). This is in line with previous research showing strong associations between WM and EPT performance (Borella et al., 2017). Moreover, WM training may even lead to improved EPT performance (Cantarella, Borella, Carretti, Kliegel, & de Beni, 2017).

Critically, EPT performance was also related to gaming activities, with this relationship being fully mediated by WM. Post hoc, given the arguably cognitive nature of the EPT and the cognitive challenge of gaming activities, it seems plausible that the relation between gaming activities and test-based functional ability, and its mediation by working memory, may only be observed if the activities and measures of functional ability are all cognitively demanding to a certain degree. Hence, benefits of an engaged lifestyle may be more domain-specific than has been previously assumed. This is consistent with research showing similarly narrow and domain-specific effects of other lifestyle influences such as bilingualism (e.g., Oschwald, Schättin, von Bastian & Souza, 2018) and cognitive training (e.g., von Bastian, Guye & De Simoni, in press). Thus, while the engagement in cognitively challenging everyday activities such as gaming may build a cognitive reserve and promote compensatory scaffolding, the resulting benefits may be limited to cognitively challenging measures of functional ability. Given the correlational nature of our study, it remains however unclear whether gaming activities can enhance WM capacity and in turn functional ability in real life settings, or whether individuals who are more likely to engage in gaming activities simply have higher levels of WM and functional ability.

In contrast, the association between sports activities and self-reported everyday failures in everyday life was not mediated through WM. Although there is evidence for physical activity being positively associated with cognitive functioning (e.g., Gow, Mortensen, & Avlund, 2012; Renaud, Bherer, & Maquestiaux, 2010) and exercise training enhancing cognitive functioning (e.g., Bherer, Erickson, & Liu-Ambrose, 2013 for a review), other studies did not find such a pattern (e.g., Dik, Deeg, Visser, & Jonker, 2003). One possibility for the absence of an effect of WM on self-reported everyday failures may be the nature of the CFQ questionnaire. In their study, Könen and Karbach (2018) found that CFQ performance was positively related to personality traits (e.g., neuroticism) but not to test-based cognitive performance. They argue that negative affectivity (rather than generally lower cognitive ability), a core aspect of neuroticism, may interfere with completing everyday life tasks, such as experiencing minor incidents as more threatening. In addition, this could lead to a lack of insight, potentially misestimating and misreporting everyday failures. Thus, the CFQ may rather reflect the personality and affectivity of a person than actual cognitive or motor performance in everyday life.

Limitations and Future Directions

Despite several strengths of the study such as considering a wide range of lifestyle activities and both self-reported and test-based measures of functional ability, and assessing WM on the latent-variable level, we also acknowledge several limitations of the present work.

Surprisingly, social activities were neither related to test-based nor self-reported functional ability. One possible reason for this lack of associations is that the measure to assess social activities used in this study does not capture well social interactions and activities that happen by technological modes of communication (i.e., short messaging, e-mails, video calls). Given the increasing use of those communication methods, the level of social activity may thus have been underestimated in our sample. Future work would benefit from updated and more reliable measures of leisure activities that better reflect contemporary modes of communication and can better identify which characteristics of social activities can be beneficial for cognition.

Although we used the adult leisure activity questionnaire (Jopp & Hertzog, 2010), a standard instrument to measure participation in lifestyle activities, we observed relatively low reliabilities for the subscales. In addition, as is true for other retrospective, self-report measures, it is potentially prone to retrospective memory bias and other biases such as attentional bias caused by anxiety (see discussion on CFQ above), especially in older adults, potentially contributing to the relatively low reliability of the measures. More objective tools such as smartphone accelerometers or GPS could be used to assess physical activity and mobility range; social interactions could be assessed with experience sampling tools such as the Electronically Activated Recorder (EAR; Mehl, Pennebaker, Crow, Dabbs, & Price, 2001). Such devices may provide ecologically valid information on daily activities from naturalistic observations.

Further, although we accounted for the fact that lifestyle activity is not a unidimensional construct by differentiating between various activity domains (e.g., intellectual, social or physical activities), this approach prevented us from considering that some lifestyle activities might consist of multiple components. For instance, sports activities, depending on the exact type of activity (e.g., running vs. team sports) may also involve a considerable amount of social interaction, and this may also vary between individuals (e.g., running in teams or running alone). Future studies should therefore make an effort to develop measures that account for multiple components of lifestyle activities.

In addition, there are only few existing measures to assess test-based functional ability in healthy older adults. The EPT is a standardized measure assessing problem solving skills in everyday life. However, the multiple-choice format might not accurately represent the occurrence and the quality of tasks of everyday life might not accurately represent the occurrence and the quality of tasks of everyday life. Further, given the limited availability of measures to assess both test-based and self-reported functional ability, we were unable to model functional ability as a latent variable. Thus, to more adequately assess functional ability and to identify modifiable determinants of functional ability that enable healthy aging, the development of ecologically valid and reliable measures is crucial.

Another limitation of the present work is the cross-sectional nature of the study design. Hence, we could not establish a causal relationship between the variables of interest. Future studies should adopt a longitudinal design to investigate the directionality of the effects to provide a more profound basis for deriving recommendations for lifestyle and lifestyle changes in older adults. Furthermore, the present study focused solely on interindividual differences. Longitudinal studies would allow for discriminating within- and between-person relationships of an engaged lifestyle and functional ability, and the potential underlying mechanisms (e.g., cognitive functioning). One possibility would be to use ambulatory assessment technologies for assessing and modeling dynamic changes in lifestyle activity participation, cognitive performance, and functional ability status in everyday life (e.g., Connor & Mehl, 2015) to examine whether high-engagement days or weeks are those on which participants perform particularly well in WM tasks and show higher than average functional ability.

We are confident that in addressing these limitations while following the methodological advantages of the present study, future work will be able to complement our initial findings and shed light on how inter- and intraindividual differences in how people live their lives relates to their cognition and overall functional capacity in daily life.

Conclusion

In sum, this study revealed that sports and gaming activities are related to WM, and self-reported and test-based functional ability to varying degrees. Whereas sports activities were solely related to self-reported functional ability, gaming activities were related to both WM and test-based functional ability. Moreover, WM predicted test-based, but not self-reported, functional ability. Finally, the association between gaming activities and test-based everyday performance was fully mediated by WM performance. No such associations emerged for any other lifestyle activities (e.g., social activities) with neither WM nor functional ability. Given the cognitive nature of gaming activities and the test-based functional ability measure, this pattern of findings suggests that while an engaged lifestyle can benefit functional ability, those benefits may be limited to highly similar domains.

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Tables

Table 1

Descriptive Statistics

Measure	*M* ± *SD*	Range	Skew	Kurtosis
	Engaged lifestyle			
Experiential activities	3.32 ± 0.63	1.83 – 4.67	0.08	-0.62
Developmental activities	2.36 ± 0.48	1.33 – 3.67	0.28	-0.14
Gaming activities	2.59 ± 0.88	1.00 – 4.80	0.11	-0.68
Technological activities	3.28 ± 0.79	1.33 – 5.33	0.12	-0.56
Social-private activities	3.18 ± 0.65	1.67 – 4.67	0.02	-0.39
Social-public activities	1.79 ± 0.56	1.00 – 3.50	0.72	0.06
Sports activities	3.11 ± 0.83	1.33 – 4.83	-0.04	-0.60
	Working memory			
Complex span Storage accuracy	0.27 ± 0.17	0.00 – 0.74	0.43	-0.68
Brown Peterson Storage accuracy	0.32 ± 0.15	0.00 – 0.75	0.23	-0.44
Memory updating locations Accuracy	0.39 ± 0.16	0.02 – 0.70	-0.04	-0.81
Memory updating arrows Accuracy	0.29 ± 0.16	0.08 – 0.79	0.62	-0.50
Binding triangles *d'*	1.00 ± 0.60	-0.61 – 2.54	0.16	-0.27
Binding shapes *d'*	1.06 ± 0.60	-1.08 – 2.68	-0.51	0.82
	Functional ability			

Self-reported everyday failures	2.19 ± 0.41	1.13 – 3.41	0.27	0.37
Test-based everyday performance	24.97 ± 3.73	9.00 – 30.00	-1.49	2.63

Figures

Figure 1. Schematic summary of the results of the mediation analyses, testing the mediating role of working memory (WM) for self-reported everyday failures (sr-EF; left) and test-based everyday performance (tb-EP; right). Panel A represents results for intellectual activities, panel B for social activities, and panel C for physical activities. Significant effects are indicated by solid arrows, non-significant effects by dotted arrows. Significant total effects (*c* paths) are indicated by asterisk.

*$p < .05$.

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