VIDEO GAME USE AND COGNITIVE FUNCTION AS INDICATORS OF QUALITY OF LIFE: A CLUSTER ANALYSIS

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Abstract

Research has established the association between lifestyle factors and cognition. However, they are often assessed in isolation overlooking their complex interaction and contribution to the quality of life (QoL). The present study seeks to determine if BMI, lifestyle behaviours (video game use, dietary intake, physical activity, sleep), and cognitive functions could be identified into distinct grouping clusters. In addition, the QoL of the resultant clusters was also examined for differences between them. Data were collected from an online survey (N = 116). Following a 2-step cluster analysis, two distinct clusters were identified with significant differences in video game use and reasoning ability were found between them. Further comparison of demographics and QoL showed a cluster of participants who played more games and had higher cognitive performance exhibited lower QoL compared to the other cluster, specifically in the ‘relationship’ dimension. The findings show video game use and reasoning ability are linked to perceived QoL. Further studies should investigate the interaction between video game use and cognitive functions and how they contribute to perceived QoL.

Keywords: Cognitive function, Video game, Quality of life, Cluster analysis, Lifestyle behaviours

Introduction

Existing literature report that adherence to healthy lifestyle behaviours promote wellbeing. This is demonstrated by a better quality of life (QoL) with regular physical activity and balanced dietary intake (1, 2). Positive QoL experience among healthy adults is also linked to good and sufficient sleep, an association found moderated by various factors such as age (3) and work schedule (shift work) (4). With the increasing prevalence of video game use (5, 6), it is crucial to examine the relation between video gaming and QoL. The findings are mixed thus far with studies claiming video games either enhanced (7), worsened (8) or had no effect on QoL (9). In addition to lifestyle factors, cognitive functions have been reported to be linked to QoL, whereby adults experiencing cognitive decline were more likely to have lower QoL (10) and vice versa (11). The wealth of evidence points out the importance of these factors in influencing life satisfaction.

The QoL has a great utility in health promotion research serving as a parameter for health intervention efficacy to guide decision making (12). The QoL was conceptualised based on subjective evaluation of several physical and psychosocial domains (13), according to its definition, “an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns” (14). However, only a few studies examined the multivariate interaction of lifestyle and cognitive factors in healthy populations, whereas a majority examined these factors in isolation. Cluster analysis is a tool that addresses such interaction by identifying variables that share similar patterns to form distinct groups allowing the detection of important variables influencing such patterns (15). For example, Rebar and colleagues (16) showed aspects of physical activity and mental health when grouped together formed three distinct health profiles, each differed in their physical-related QoL. In another study, four groupings of health functioning were identified from demographics, alcohol consumption and walking behaviour in older adults, with the degree of life satisfaction corresponding to the levels of physical and psychological functioning (17). Assessment of active and passive leisure activities found a prevalence for video game use and computer-related activities in an older population, a pattern of activity which remained stable over a 4-year period (18). These findings demonstrate how evaluating the complex interaction within a set of contributing factors enables identification of predictors. This type of study analysis provides conceptual insights for future health promotion research targeting QoL.

The present work aims to explore the multivariate interaction of variables by determining whether body mass index (BMI), lifestyle behaviours and cognitions have shared characteristics (homogeneity) resulting in distinct clustering of participants. Lifestyle behaviours assessed were video game use, physical activity, dietary intake, and sleep. For cognitions, functions such as processing speed, updating, and reasoning were assessed. The resultant clusters were further compared for their differences in the perceived QoL. The findings gathered are expected to describe (i) which among these variables emerges as the prevalent predictor of QoL within the clusters and (ii) how the clusters differ in their demographics and perceived QoL.

Materials and Methods

An online survey assessing demographics, lifestyle behaviours, cognitive functions and QoL of adults was administered using Qualtrics software (Provo, Utah, USA) and completed using a computer (Windows, iMac) or mobile devices (Android, iPhone, tablet, iPad). Advertisements were run through email, social media (Facebook, Twitter, WhatsApp), blogs and social forums, targeting adults aged 18 and over. The survey was conducted between June 2017 to May 2018, and participants who completed the survey were included in a draw to win AU$150 at the close of the survey. Data from participants taking medications with known neuropsychological effects (19) were excluded. Before survey commencement, participants were provided with the details of the study and proceeding to respond to the questions was considered consent for participation. The University of Sydney Human Research Ethics Committee approved the project (No.: 2017/199).

Demographics

Data collected were age, sex, height, weight, education, and employment status. Body mass index (BMI) was determined using collected height and weight information (Normal range: 18.5 - 25 $kg.m^{-2}$).

Lifestyle behaviours

Video game use: Participants were categorised as gamers if they regularly played for the past six weeks and as non-gamers if otherwise. The aspects of video game use reported were weekly gaming frequency and time spent per session. Estimation of total video gaming duration was the product of gaming frequency and time spent per session. Information regarding gaming preference, characterised by the type of games, timing and mode of gaming, was also recorded.

Physical activity: Participants were asked to estimate the time spent performing various physical activities on an average weekday using the Physical Activity Scale (20). In this scale, a number of commonly performed activities were categorised in ascending order of the level of energy expenditure attributed by metabolic equivalent of task (MET) (Level A = 0.9 METs, Level B = 1.0 METs, Level C = 1.5 METs, Level D = 2.0 METs, Level E = 3.0 METs, Level F = 5.0 METs, Level G = 6.0 METs, and Level I > 6.0 METs). Scale validation indicated strong correlation with physical activity log diary ($r = 0.82$, $p<0.001$), but no association with accelerometer ($r = 0.20$, $p = ns$) (20). The level of physical activity was measured by the total sum of the MET-value of each level multiplied by the hours spent at that level.

***Dietary intake*:** The Dietary Fat and Free Sugar - Short Questionnaire (DFS) (21) was used to assess the intake frequency of food high in saturated fat and free sugar over the preceding twelve months using a 5-point Likert scale (1 = Less than 1 time/month; 2 = 2-3 times/month; 3 = 1-2 times/week; 4 = 3-4 times/week; 5 = 5 or more times/week). The scale consisted of 24 items of high-calorie food (e.g., burgers, eggs, pizza), and two items asking about food eaten outside the home (e.g., fast food restaurant) and added sugar in beverages. The scale has a moderate-to-high correlation to items measuring saturated fat and/or free sugar in other dietary measures (food frequency questionnaire, diet diary) (21). The primary outcome was the overall dietary intake i.e., the sum of all item responses (minimum score = 26, maximum score = 130).

***Sleep*:** The Verran and Snyder-Halpern (VSH) Sleep Scale (22) scale provided a measure of the degree of sleep disturbance and sleep effectiveness over the preceding three nights. Sleep disturbance was assessed by items asking about sleep latency, soundness of sleep, fragmented sleep, and movement during sleep. Sleep effectiveness was assessed using items on sleep duration, rest upon awakening, and perceived sleep quality. Participants rated each item using a 7-item visual analogue scale rated from 0 to 100. Sleep quality was determined by averaging the items assessing the domains (sleep disturbance, sleep effectiveness) into a percentage (Min = 0, Max = 100) with a higher score indicating a greater value for a specific domain (e.g., a larger score for the sleep disturbance domain indicated greater sleep disturbance).

Cognitive functions

Processing speed: This function was assessed using a 3-choice reaction time test, which aimed to measure participants' responses to a changing screen colour by clicking the assigned button, as quickly and accurately as possible. Three colours were displayed. A changing red or blue colour required participants to press a corresponding button while a yellow colour required no button click. At the end of each trial, participants clicked the "NEXT" button to proceed to the next trial. Participants completed a block of 15 trials (5 of each colour) preceded by optional practice trials for test familiarisation. The order of appearance of the colours was randomised through embedded Javascript functions in Qualtrics. The time differences between the stimuli (colour appearance) and response (clicking the correct button) were reported as reaction time, an outcome measure for processing speed. Only correct responses, with reaction times ranging between 100ms and 1100ms, were considered for analysis (23, 24).

***Updating memory*:** The re-drawn Vandenberg & Kuse version (25) of the Mental Rotation Test (MRT) consisted of twenty target figures of 3-dimensional objects. Each object was presented with four potential alternatives to its rotated version with only two out of the four being correct options. To minimise the chances of guessing, a point for an item was only awarded if both correct answers were selected. Participants were asked to respond to as many items as possible within six minutes and the primary outcome measure was the ratio of the number of correct answer to the total attempted responses (26).

Reasoning: The Shortened Raven's Standard Progressive Matrices (RSPM) (27) measured participants' reasoning ability using three sets of twelve geometric matrices (Set B, Set C, Set D). Each matrix had a piece cut out of it, and participants needed to determine which of the answer options fits the given matrix. Participants needed to work out the rule of each matrix to determine which one of the provided answers fits the rule. The matrices progressively increased in difficulty. Participants were required to complete as many items as possible within a 10-minutes duration. The outcome measure of the test was the number of correct responses with a maximum score of 36. Practise trials preceded these cognitive tests for familiarisation to reduce the learning effect.

Quality of life

Perceived QoL of physical and psychosocial dimensions for the past week was assessed using the Assessment of Quality of Life (AQoL) scale (13). Conceptualisation of the scale's development was in reference to the World Health Organization's (28) definition of quality of life, i.e., "individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns". The scale consisted of twelve items, each with four levels of multiple-choice item responses, assessing participants' physical (independent living, senses) and psychosocial dimensions (mental health, relationship). The scale had a high internal consistency (Cronbach $\alpha = 0.81$) (13) and the perceived QoL was reported by the overall mean score as well as by its four individual dimensions. Interpretation of QoL scores were based on mean comparisons to population norms (Overall AQoL Mean ± SD = 0.81 ± 0.22) (29), significant difference between groups ($p<0.05$) and effect sizes (Cohen's d) (30).

Analysis

Body mass index (BMI) was calculated as body mass (kg) divided by the height (m) squared. Data were analysed using Statistical Programme for Social Sciences (SPSS) Version 24 and sample demographic characteristics were reported using descriptive analyses (mean, standard deviation, frequency, percentage). The 2-step cluster analysis method was performed to determine whether there were distinct clusters based on the standardised data of BMI, lifestyle behaviours and cognitive functions. The variables were standardised to z-scores to ensure each measure contributed equally to the formation of the clusters as different variances across variables may have different effects on the resulting clusters (31). The scores were calculated by dividing the difference between the population mean and raw score with standard deviation. The number of clusters was determined using Akaike's information criterion (AIC) based on the similarity of values of a set of variables in a group compared to another. The best model was determined by the log-likelihood distance measure, a measure of the dissimilarity of the clusters (15), and cluster quality (-1.0 = Poor, 0.3 = Fair, 0.5 = Good). These indicators reported on the within-group homogeneity and between-group heterogeneity. To determine the relation between the resultant clusters and demographics as well as QoL, the estimated overall means were tested for differences between clusters. Independent t-tests, or chi-square for categorical variables, were used if only two clusters were identified, or Analyses of Variance were used if three or more clusters were identified. The magnitude of differences between clusters for QoL were represented by Cohen's *d* (0.20 = small effect, 0.50 = moderate effect, 0.80 = large effect). Datasets with missing values were omitted, retaining only complete-case data for analysis (15). A significance level of $p < 0.05$ was used. Means and standard deviation (SD) are reported unless otherwise stated.

Results

Clusters profile

Of the 383 responses, 267 were excluded due to incomplete surveys. The final number of responses included in the analysis was 116. The 2-step cluster analysis yielded two distinct clusters based on the AIC (AIC = 992.2) and the highest log-likelihood distance measure (ratio of distance measures = 2.319). Model quality was rated fair at 0.4. There was 81.0% (n = 94) of participants in Cluster 1 with the remaining 19% (n = 22) in Cluster 2. Table 1 presented the clusters profile. When lifestyle and cognitive factors were compared between clusters, significant differences were found in video game use and reasoning. This is indicated by participants in Cluster 2 reporting to have spent more time video gaming at each session (4.00 ± 2.28 hours) and per week (14.96 ± 7.61 hours); and played games more often (4.55

± 2.15 times) than those in Cluster 1 (Duration per session: 0.38 ± 0.85 hours, p < 0.001; Total duration per week: 0.60 ± 1.43 hours, p < 0.001; Frequency per week = 0.35 ± 0.83 times, p < 0.001). For reasoning, participants in Cluster 2 (30.36± 2.75 out of 36) outperformed those in Cluster 1 (28.21 ± 5.01 out of 36, p = 0.008). No group differences were found for other lifestyle behaviours, BMI, and cognitive factors (p > 0.05).

A graphical illustration of between-group standardised Z-scores across variables is presented in Figure 1 and Figure 2 as supplementary.

Table 1: Clusters profile of BMI, lifestyle behaviours and cognitive functions

Variables	Mean ± SD		t	df	p
	Cluster 1 (n = 94)	Cluster 2 (n = 22)			
BMI ($kg.m^{-2}$)	23.03 ± 3.75	22.97 ± 3.47	0.63	114	0.947
Physical activity (MET.hr/daily)	43.77 ± 8.98	40.48 ± 8.46	1.562	114	0.114
Total gaming duration (hr/week)	0.60 ± 1.43	14.96 ± 7.61	-8.818	114	<0.001*
Gaming frequency (times/week)	0.35 ± 0.83	4.55 ± 2.15	-8.979	114	<0.001*
Gaming duration (hr/session)	0.38 ± 0.85	4.00 ± 2.28	-7.238	114	<0.001*
Sugar (score)	11.31 ± 3.34	13.18 ± 4.62	-1.797	114	0.084
Saturated fat (score)	24.59 ± 5.24	26.25 ± 5.27	-1.318	114	0.190
Saturated fat & Sugar (score)	17.02 ± 4.33	17.41 ± 4.33	-1.055	114	0.294
Sleep disturbance (%)	39.90 ± 19.27	38.49 ± 26.92	0.232	114	0.673
Sleep effectiveness (%)	61.93 ± 18.30	60.07 ± 19.46	0.424	114	0.818
Processing speed (ms)	791.63 ± 33.97	741.44 ± 143.28	1.561	114	0.145
Updating (ratio)	0.54 ± 0.27	0.64 ± 0.27	-1.674	114	0.110
Reasoning (score)	28.21 ± 5.01	30.36 ± 2.75	-2.750	114	0.008*

*Significantly different at p<0.05

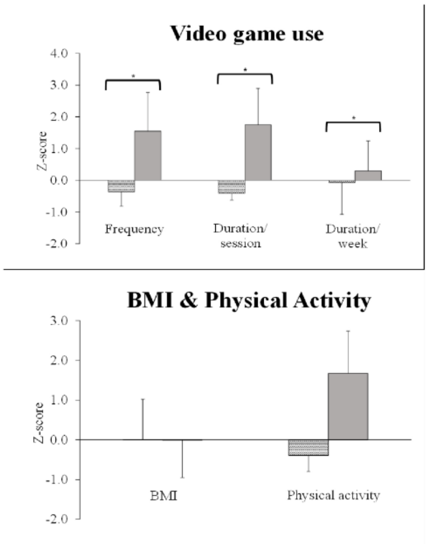

Figure 1: Standardised Z-scores and standard deviation bars of BMI, physical activity and video game use

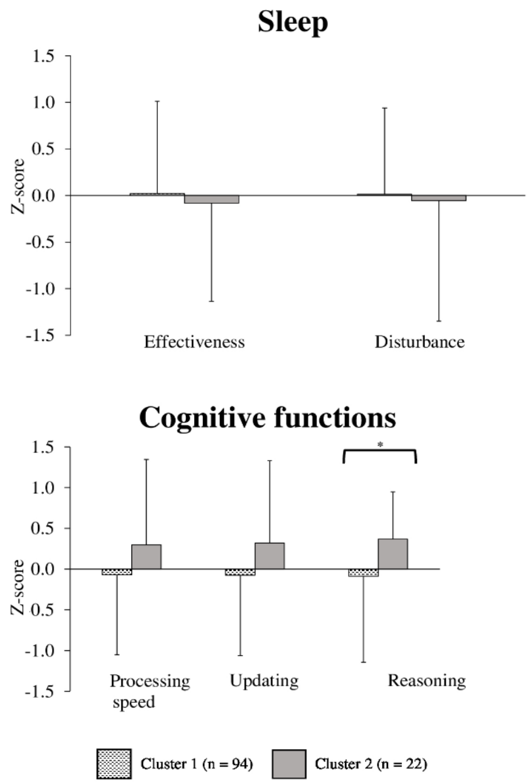

Figure 2: Standardised Z-scores and standard deviation bars of sleep and cognitive

Differences in demographics and QoL between clusters

The two resultant clusters were further compared to determine if the participants of clusters had different (i) demographic characteristics and (ii) perceptions of their QoL. As shown in Table 2, there is a significant difference in male-female proportion between clusters; Cluster 2 has a significantly larger male proportion (40.9%) than Cluster 1 (19.1%). No group difference was found in other demographic variables. For QoL, Cluster 1 (0.76 ± 0.17) has higher overall QoL than Cluster 2 participants (0.61 ± 0.25, p = 0.013, d = 0.70). However, the overall AQoL mean score of Cluster 1 and 2 were 0.76 (SD = 0.17) and 0.61 (SD = 0.25), respectively; both indicated lower score than overall mean score than population norms (Mean ± SD = 0.81 ± 0.22). In addition, among the physical and psychosocial dimensions examined, only the relationship domain was significantly different between the clusters (Cluster 1: 0.89 ± 0.10; Cluster 2: 0.79 ± 0.21, p = 0.046, *d* = 0.61).

Discussion

The analysis yields two distinct clusters of participants characterised by BMI, lifestyle behaviours and cognitive functions. Cluster 2 reported greater video game use and had higher reasoning ability than Cluster 1. However, Cluster 1 had significantly higher perceived QoL than Cluster 2. Video game use emerged as a significant factor in the clusters. Research studying the pattern of daily time use highlighted electronic media use, i.e., video games by a computer or mobile phone as one of the common leisure activities (6, 18, 32). The prevalence of video gaming activity is supported by the steady increase in the proportion of video gamers across age groups (5) potentially due to its greater accessibility through internet gaming (33). Greater video game use in Cluster 2 is potentially attributed to the larger male proportion in this cluster compared to Cluster 1. When describing gamers' demographics, previous studies noted differential gaming tendencies between sexes. This is described by a larger proportion of male gamers among young adults (aged < 30 years) (34), and if the studies had similar male-female proportion, male gamers showed higher engagement with video gaming activity (time spent, frequent use, easier adoption and maintenance of gaming habit) (35, 36). Participants of Cluster 2 who reported higher video game use also exhibited higher reasoning ability. Cognitive enhancement from video gaming has been reported not only in reasoning (37), but also in processing speed and attention (38), updating, inhibition and shifting (39). The literature is consistent in demonstrating the cognitive superiority of video gamers over non-gamers (40). However, there is lack of understanding on the factors influencing video games' effects on cognition. For example, there is a lack of consensus on the range of optimal video game use, e.g., the frequency and gaming duration for maximal cognitive effects (41). Also, previous research suggested the type of video game (action, casual, brain training, exergame) may differentially impact cognitive functions (42). On the other hand, research suggests greater cognitive abilities may influence one's selection of preferred video games. For example, players with faster processing speed and better updating functions preferred action games, whereas those with higher reasoning ability selected problem-solving games (43).

Table 2: Differences in demographics and QoL between clusters

Demographic		Mean ± SD Cluster 1 (n = 94)	Cluster 2 (n = 22)	t	df	p
Age		25.60 ± 9.66	23.09 ± 5.66	1.168	114	0.245
		N (%)				
Sex[a]	Male	18 (19.1)	9 (40.9)		1	0.047*
	Female	76 (80.9)	13 (59.1)			
Education[a]	Secondary	23 (24.7)	9 (40.9)		1	0.184
	Tertiary	70 (75.3)	13 (59.1)			
Employment[a]	Employed	51 (54.3)	8 (36.4)		1	0.159
	Unemployed	43 (45.7)	14 (63.6)			

QoL	Mean ± SD Cluster 1 (n = 94)	Cluster 2 (n = 22)	t	df	p	d
Overall	0.76 ± 0.17	0.61 ± 0.25	2.670	114	0.013*	0.70
Independent living	0.95 ± 0.12	0.89 ± 0.16	1.644	114	0.112	0.42
Senses	0.95 ± 0.08	0.90 ± 0.14	1.666	114	0.109	0.44
Mental Health	0.92 ± 0.08	0.88 ± 0.11	1.686	114	0.095	0.42
Relationship	0.89 ± 0.10	0.79 ± 0.21	2.110	114	0.046*	0.61

Group differences were determined by independent t-test for continuous variables and [a]chi-square test for categorical variable, *Significantly different at p<0.05

Additionally, adults were less likely to use electronic media as they got older, a usage tendency linked to the decrement in cognitive functions (44). The present findings lent support for the significance of video games and reasoning in relation to other variables contributing to QoL, yet there is a lack of clarity if these factors have any direct association.

Clusters 2 (greater video game use, higher reasoning ability) reported worse overall QoL, especially in its relationship domain, compared to participants in Cluster 1 (lesser video game use, lower reasoning ability). Although internet gaming promoted positive online social interaction (45), the present finding suggested otherwise for offline social relationships (partner, friends and family). It has been suggested that the increased video game use predicted higher dissatisfaction and conflict in close relationships (46). This may be due to the displacement effects of video games where the time with significant others is displaced by the time spent gaming (47) resulting in negative relationship experiences. Although video gaming with significant others may foster quality time together for a better relationship experience, the content of video games (such as the graphic portrayal of violence and sex) could contribute to intimate relationship conflict (46). Exposure to violent content was associated with an increase in aggressive thought and behaviour, and a decrease in empathy and prosocial behaviour (48). Additionally, unrealistic gender roles and expectation towards the opposite sex due to the internalisation of sexist game content (49) also contributed to poor intimate relationship satisfaction.

The lack of groups difference in the remaining factors i.e., BMI, physical activity, dietary intake, sleep, processing speed, and updating further highlighted the importance of video game use and reasoning ability as factors distinguishing perceived QoL. Previous findings showed greater video game use and reasoning ability, when examined in isolation, contributed to a better quality of life (50). Yet, when these two factors were examined together, along with other lifestyle and cognitive factors, participants who reported higher video game use and scored better in the reasoning measure had lower QoL. The discordance between the present and previous findings warranted further exploration on the relations between video game use, cognitions and QoL. However, due to the nature of the analysis, the present study was not able to infer the direct relationship between video games use and cognitive function, and how they contributed to QoL. However, a number of limitations of the present study are worth noting. Subjective evaluation of lifestyle activity and QoL may influence participants to respond in a socially desirable manner. Also, the reaction time test had not been tested for validity and reliability. Thus, keeping in mind these limitations, the findings presented should be treated with consideration.

Conclusion

In summary, adults who reported playing more video games and had higher reasoning ability experienced lower QoL. Those who played fewer video games and had lower reasoning ability, however, experienced higher QoL. A better understanding of the interaction between video games and cognition will better provide a more comprehensive view of contributory factors to QoL and evaluate the usability of the video game as a potential health intervention tool.

Competing Interests

All the authors declare no conflict of interest.

Ethical Clearance

Ethical clearance was obtained from the University of Sydney Human Research Ethics Committee (Project No.: 2017/199). Respondents were provided with information regarding the study. All data were kept confidential, and personal data will not be disclosed to any parties. Only group data will be reported in this study. Permission from the institutions involved in this study were obtained prior to data collection.

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