Original Research

DIGITAL HEALTH

Digital Health
Volume 8: 1–15

DOI: 10.1177/20552076221139090
journals.sagepub.com/home/dhj
SAGE

Screen media and non-screen media habits among preschool children in Singapore, South Korea, Japan, and Finland: Insights from an unsupervised clustering approach

Michael Chia[1], John Komar[1], Terence Chua[1], Lee Yong Tay[2], Jung-Hyun Kim[3], Kwangseok Hong[3], Hyunshik Kim[4], Jiameng Ma[4], Hanna Vehmas[5] and Arja Sääkslahti[5]

Abstract

The main purpose of the research was to describe the daily screen media habits and non-screen media habits like indoor and outdoor play, and sleep of preschool children aged 2 to 6 years from Singapore, South Korea, Japan, and Finland using a content-validated online questionnaire (SMALLQ®) and unsupervised cluster analysis. Unsupervised cluster analysis on 5809 parent-reported weekday and weekend screen and non-screen media habits of preschool children from the four countries resulted in seven emergent clusters. Cluster 2 ($n = 1288$) or the *Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family* made up 22.2% and Cluster 1 ($n = 261$) or the *High-all-round activity and screen media-late family* made up 4.5%, respectively represented the largest and smallest clusters among the seven clusters that were emergent from the pooled dataset. Finland was best represented by Cluster 2 and Japan was best represented by Cluster 3 (*High-screen media-for-entertainment and low-engagement family*). Parents from Finland and Japan displayed greater homogeneity in terms of the screen media and non-screen media habits of preschool children than the parents from South Korea and Singapore. South Korea was best represented by Clusters 6 (*Screen media-physical activity-engagement hands-off family*) and 7 (*Screen media-lite, screen media-late and high-physical activity family*). Singapore was best represented by Clusters 4, 5, 6 and 7, and these clusters ranged from *Low all-round activity-high nap time family* to *Screen media-lite, screen media-late and high-physical activity family*. Future research should explore in-depth reasons for the across-country and within-country cluster characteristics of screen media and non-screen media habits among preschool children to allow for more targeted interventions.

Keywords

Lifestyle habits, preschool children, Singapore, South Korea, Japan, Finland, unsupervised clustering

Submission date: 29 November 2021; Acceptance date: 28 October 2022

Background and rationale

Research suggests that how time is spent in the first five years of life matters in terms of brain development and other developmental milestones.[1] Early experiences in children's lives are associated with important later-in-life outcomes like physical and mental well-being and educational attainment.[2–4] In the present study, screen digital media habits are daily routines adopted by parents and children that are characterized by use of different stationary and mobile devices, multitasking with several media and activities simultaneously, and allocating of varying degrees of attention to each competing pursuit.[5] Conversely, non-screen

[1]Physical Education and Sports Science Academic Department, National Institute of Education, Nanyang Technological University, Singapore
[2]Office of Education Research, National Institute of Education, Nanyang Technological University, Singapore
[3]Department of Physical Education, Chung-Ang University, Seoul, South Korea
[4]Faculty of Sports Science, Sendai University, Shibata, Japan
[5]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

Corresponding author:
Michael Chia, Physical Education and Sports Science Academic Department, National Institute of Education, Nanyang Technological University, Singapore.
Email: michael.chia@nie.edu.sg

media habits are daily activities that do not involve the use of screen digital media devices. Examples of such activities gleaned from previous studies are indoor and outdoor play, and sleep.[6] According to the socioecological model, parent behaviour can influence that of children at this period of early years. Parent screen digital media habits and home as an immediate environment within the context of a family are important characteristics when considering screen digital media habits of preschool children.

Screen media and non-screen media habits in association with movement guidelines

There has been a move towards adoption of movement or activity integrated guidelines for children in recent years given that the day is made up of sleep time, sedentary time, and light, moderate- or vigorous-intensity physical activity. The World Health Organisation (WHO) guidelines on physical activity, sedentary behaviour, and sleep for young children under 5 years of age are one such integrated guideline. For example, it is recommended that for children ages 3 to 4 years old to gain the greatest health benefits, they should: (i) spend at least 3 hours of physical activity of which at least 1 hour is moderate-to-vigorous physical activity; (ii) not be restrained for more than 1 hour at a time and when screen media is used, sedentary screen time should be limited to no more than 1 hour and (iii) have 10 to 13 hours of good quality sleep over a 24-hour period.[7] As inactive screen media use is usually performed while seated for a period of time, this activity is considered as a constituent of sedentary behaviour. Screen-based activities are increasingly prevalent among children in this digital age and those who spent excessive sedentary screen time have a higher risk for overweight and obesity.[8] Physical activity, sedentary behaviour, and sleep are important activities that can potentially influence and shape behaviours later in life and hence, it is worth considering how different preschool-aged children spend their time differently on each of these activities throughout a day.

Parent screen media habits and engagement of screen media with child

Parents play an important role as role models in shaping child's screen media habits especially during the early years of childhood. Studies showed that parent's screen-viewing time has significant association to the screen-viewing time of child.[9] The quality of child's digital screen media experience is not only dependent on the educational value of the media content a child is exposed to but the quality of interaction between the parent and child. For instance, parents playing an active mediation role (e.g. when parents communicate and discuss with children about characters or themes from a media programme) instead of a passive role can help safeguard their children's digital media experience and enhances the quality of parent–child interactions.[10]

Application of unsupervised clustering methods to time-use and lifestyle behaviours

Clustering is a powerful machine learning tool for detecting structures in datasets and is emerging as a useful tool for disease diagnosis in medicine.[11] In the context of the present study and preventative medicine clustering may provide new insights for future health counseling or interventions among families with young children who are in need or more vulnerable to imbalances in screen media and non-screen media habits among preschool children. The main purpose of clustering is to organize data into groups or objects of similar characteristics so that information about the dataset is simplified.[12] Unsupervised clustering is a useful tool for understanding behavioural patterns such as movement and diet patterns in children.[13] The use of K-means is an unsupervised machine learning approach to partitioning data that makes no *a priori* assumption about the specific variable scores.[14] For instance, the unsupervised clustering treatment of data was used to derive three distinct clusters of healthy, unhealthy and mixed in diet and movement behaviour research.[13] In the cluster identified as healthy, the authors were able to discern that children who were in this healthy cluster reported having high fruit and vegetable intake and high levels of outdoor play, and conversely those in the unhealthy cluster had low fruit and vegetable intake or high discretionary food intake and high levels of sedentary behaviour.[13] Still, the use of machine learning techniques such as unsupervised clustering of screen media and non-screen media habits data of preschool children within countries is apparently unexplored and none have been used in across-country analysis. Results of such an approach can provide a more nuanced understanding of the daily screen and non-screen media habits of preschool children living in Singapore, South Korea, Japan, and Finland and allow for more targeted approaches at addressing the daily screen media and non-screen media habits of preschool children across different countries.

Research objectives

The objectives of the research were (i) to apply an unsupervised clustering technique to daily screen media and non-screen media habits of preschool children living in Singapore, South Korea, Japan, and Finland, and to describe the characteristics of the emergent clusters for

the four countries combined, and (ii) to explain the clusters that best described the daily screen media and non-screen media habits of preschool children, respectively for Singapore, South Korea, Japan and Finland.

Methodology

The research was performed in accordance with the Declaration of Helsinki. Overall research approval for the study was obtained from the Human Research Ethics Committee of the Nanyang Technological University in Singapore (IRB 2017-09-036 and IRB 2019-02-036). The research is part of a larger international study called International iPreschooler Surveillance Study Among Asians and otheRs (iissaar.com) and represented the first cross-sectional results of the four countries that successfully completed the first round of data collection in 2019, prior to any movement restrictions imposed because of the COVID-19 pandemic.

Instrument

Surveillance of digital Media in eArLy chiLdhood Questionnaire (SMALLQ®). SMALLQ® was the common questionnaire used in the four-country comparative research. The development, validity and internal consistency of the SMALLQ® were previously described and discussed.[6, 15] The SMALLQ® is not a psychometric instrument but rather a lifestyle questionnaire that elicits behavioural habits of screen media use, physical activity and sleep. The SMALLQ® used an adapted framework of screen media parenting where screen media use, physical activity and sleep were described in terms of amount, content and context.[16] The SMALLQ® solicited parent self-reported daily screen media habits media children's daily screen media and non-screen media habits under these key segments: (i) digital home environment in terms of ownership of fixed and mobile screens, (ii) parent and child screen media habits on the weekday and weekend, (iii) child non-screen media habits on the weekday and weekend like indoor and outdoor play, and sleep, and (iv) demographic information of the parent and child. Content validity of the SMALLQ® was established in accordance with the existing procedures outlined by the cited authors.[17, 18] The computed internal consistency of the SMALLQ® for Singapore, Finland, South Korea, and Japan were Cronbach's alpha values of 0.79, 0.72, 0.64 and 0.71 respectively, and was adjudged to have modest reliability. Cronbach alpha values of 0.70 to 0.90 are deemed to be valued and acceptable.[19] The original language of SMALLQ® is Singaporean English. SMALLQ® was translated to Finnish, Swedish and Russian (for Finland), Japanese (for Japan) and Korean (for South Korea) using the forward- and back-translations method used by the WHO.[20]

Participants and procedures

The descriptive cross-sectional research was conducted for parents of children who attended preschools in cities and/or municipalities in Singapore, South Korea, Japan and Finland. The four countries were adjudged on international benchmarks to be somewhat similar. For instance, the World Bank classifies the world's economies into four income groups – high, upper-middle, lower-middle and low. The four countries were classified as 'high income' and were highly placed in the 2020 United Nations Human Development Index with Singapore (0.938), Finland (0.938), Japan (0.919) and South Korea (0.916), where 1.0 is synonymous to a perfect score.[21, 22] Parents of preschool children aged between 2 and 6 years were invited to take part in the study. The SMALLQ® was hosted on Qualtrics®XM (SAP, Provo, US) and completed online for Singapore, South Korea and Finland. For Japan, parents completed the SMALLQ® in hardcopy and questionnaire data were subsequently entered in excel format by their research team. Data for the four countries were collected between March and December in 2019 prior to any imposition of COVID-19 restrictive measures in the four countries.

Country recruitment of survey respondents

Parent respondents are either fathers or mothers. Individual country recruitment of survey respondents is described below.

Singapore. Parents of children attending 425 preschools in Singapore (a tropical urbanized city state, situated 1.5 degrees north of the Equator) were recruited from 15 March to 24 September 2019. These preschools operated under a private-public enterprise arrangement called the Anchor Operator Scheme (https://www.ecda.gov.sg/Parents/Pages/AOP.aspx) (accessed on 30 August 2022). The private-public arrangement provided government-subsidized and good quality early childhood education (ECE) to the masses, and especially to lower-income and disadvantaged households. A majority of parents who enrolled their children under the Anchor Operator Scheme therefore came lower-to-middle income households. The preschool operators sent out a research invitation letter inviting parents of children enrolled in their preschools to take part in the survey. Similar survey conducted previously in Singapore showed that the ethnicity of parents represented in the poll was in close representation to the country's population profile.[23] At least half of the parents sampled had at least a bachelor's degree and most have a monthly household income ranging between SGD 2501 and SGD 12,000.

Finland. The representative Finnish sample was conducted randomly by Probability Proportional to Size (PPS)

sampling. Participants from the sample municipalities were recruited via municipal ECE centres and three private ECE centres. From a total of 56 municipalities, a total of 426 centres chose to participate. As an exception, four municipalities and the private ECE centres chose to disseminate the survey to all parents with children in all their ECE centres. In order to access speakers of minority languages, the survey was offered in four commonly spoken languages: Finnish, Swedish, Russian and English. The original SMALLQ® was translated from English to Finnish, Swedish and Russian. The data collection took place from 11 November to 1 December 2019 and the final sample represented Finnish families with preschool-aged children enrolled in ECE centre both geographically and sociodemographically. Finnish sampling procedure is explained more detailed in an earlier study. Most of the parents sampled had at least a bachelor's degree and an annual household income of at least EUR 40,000.[24]

Japan. Three childcare facilities schools in Nishinomiya and five children centres in Ōhira and Tomiya were participating sites for the study conducted in Japan. Nishinomiya is located in Hyōgo prefecture, and Ōhira and Tomiya are located in Miyagi Prefecture. These regions are classified by the 1947 Japanese Enforcement Decree of statutes of local governments. Parents of preschool children enrolled to these eight nursery schools were recruited via convenience sampling. After appropriate assent were obtained, parents completed the questionnaire tool between 1 June and 31 October 2019.[25] The language of the survey was Japanese. Most of the parents sampled had at least a post-secondary school education and a monthly household income of 200,000 yen to 600,000 yen.

South Korea. A total of 20 private kindergartens in cities such as Seoul, Incheon, Ansan and Suwon in South Korea were invited to be involved in the study. The study objectives were first presented to the director of the private kindergartens by the researchers in South Korea before invitations to take part in the survey were distributed by mail to parents of preschool children from 17 September to 21 November 2019. All participants provided both verbal and written consent prior to participation in this study. The language of the questionnaire was Korean. Most of the parents sampled had at least a bachelor's degree and a monthly household income of at least 4 million won.

Variables of interest used in clustering analysis

Child screen and non-screen digital media habits. Duration of child screen digital media habits and non-screen digital media habits were solicited from parent responses to SMALLQ®. Examples of child screen digital media use on a weekday and a weekend asked in SMALLQ® are using screen digital media for learning or educational purposes, for keeping child entertained, for communicating with relatives, and for creating media. Child non-screen digital media activities are activities without the use of screen digital media devices. These include light intensity physical activity like reading books, drawing as well as moderate-to-vigorous intensity physical activity like indoor and outdoor play that makes child breathe harder and faster as reported by parents. Duration of child daytime naps and night-time sleep on a weekday and a weekend respectively were reported by parents. Additionally, general information about the child such as age, height and weight were solicited.

Home digital environment, parent screen digital media habits and engagement with child. Information about the type of screen digital media devices that parents have at home was solicited. These included fixed screens such as television, desktop computers and game consoles, mobile screens such as smartphones, tablets and other hand-held devices and programmable toys. Parents were queried about their screen digital media habits, respectively, on a weekday and on a weekend. The activities were segregated as use for work, entertainment, social networking and for personal development. Parents were also asked in SMALLQ® for the proportion of time they spent engaged in screen-based activities and physical play with their child respectively.

Data analysis

All tests were conducted with JASP Statistics V0.11 (September 2019 – www.jasp-stats.org) and R version 3.6.0. Step 1 of the analysis involved data cleaning by removing all the answers where more than 5% of data were missing. The final pooled dataset comprised 5809 parent responses (Singapore – 2,162, 37% of total, South Korea – 927, 16% of total, Japan – 892, 15.4% of total and Finland – 1,828, 31.5% of total). Step 2 involved filling in the remaining missing values using a random forest package (miss Forest) in R 3.6.0.[26, 27] In this step, a random forest for each variable was created and thereafter the model was used to predict the missing values in the dataset with reference to the other observed variables. Step 3 involved normalizing the continuous data using a *z-score* approach so as to minimise the impact of the different individual scales that was used in the SMALLQ®. An unsupervised cluster analysis was performed on the normalized data, to identify existing patterns within the dataset.[11]

Unsupervised cluster analysis

From a machine learning perspective, clustering algorithms are useful in segregating a large dataset into different k groups or clusters without knowing a priori any grouping or label, where observations within the same group that

have the highest similarity and are sufficiently different from observations belonging to other groups are classified and clustered. In the present research, the function *kproto* from the package "clustMixType" was used to classify the observations.[28, 29] The algorithm performed large dataset clustering using K-means algorithm with mixed data consists of continuous variables (e.g. parent-reported indoor and outdoor play durations of their child in SMALLQ®) and categorical variables (e.g. parent-reported home ownership of screen digital media devices in SMALLQ®). The clustering procedure was performed on the pooled dataset from the four countries comprising the pooled parent responses to the SMALLQ®.

Naming and comparison of clusters

The optimum value of k (i.e. the optimal number of different clusters) was selected based on the McClain index where the minimum value of the index indicated the optimal number of clusters.[30] The McClain index for a potential number of clusters from 2 to 13 was explored and a decision was made on the appropriate number of clusters based upon the associated McClain values. Using this criterion, seven clusters were identified, and the key characteristics or profiles of each cluster were noted. Adjectival descriptions of each cluster (i.e. cluster name) were created based upon the significant characteristics of the parent responses to the SMALLQ®. These cluster names, in the context of the family, helped to differentiate one cluster from the other. Results for each question from the survey were expressed as a percentage of the average value across all the pooled parent responses (i.e. combined dataset of the four countries). Chi-square tests were used to investigate differences in the distribution of clusters across the countries with an a priori level of statistical significance set at $p < 0.05$.

Results

Emergent clusters for pooled datasets of the four countries

From the clustering algorithm, seven emergent 'best-fit' clusters for the pooled dataset of the four countries were identified. The optimal value of $k = 7$ was selected based upon the McClain criterion, where $k = 7$ corresponded to the minimal McClain value* (McClain = [0.827282; 0.864343; 0.746846; 0.752599; 0.732144; **0.70565***; 0.733469; 0.710202; 0.715737; 0.721037; 0.738412; 0.721979] for 2–13 clusters, respectively).[31] The number of parent respondents across the seven clusters derived from the pooled dataset of the four countries is presented in Figure 1A ($N = 5809$). In terms of number of parent responses Cluster 2 had the highest number at 1288 while Cluster 1 had the lowest number at 261. Clusters 3 and 6 had parent-response numbers, respectively of 969 and 915, followed by Clusters 4 and 5 with 829 and 822 and Cluster 7 with 725 parent responses.

Cluster distribution by countries

Figure 1B (Singapore), 1C (Finland), 1D (South Korea) and 1E (Japan) show the cluster distribution by country. The distribution of clusters was significantly different across countries [$\chi^2(18, N = 5809) = 8074$, $p < .001$]. For instance, in Figure 1B, Singapore had a prevalence of parent responses that are described in Clusters 4 and 5, Finland had a prevalence of parent responses that is described in Cluster 2 (Figure 1C), Japan had a prevalence of parent responses that is described in Cluster 3 (Figure 1E), South Korea had a prevalence of parent responses that is described in Clusters 6 and 7 (Figure 1D). Overall, Finland and Japan had somewhat similar parent response profiles with unique digital-use behaviours, whereas Singapore and South Korea had relatively more diverse parent response profiles as represented by a wider distribution of clusters that encapsulated multiple digital-use behaviours.

Cluster descriptions in terms of daily habits of screen media and non-screen media and other characteristics in the context of the family

The seven cluster distributions from the pooled dataset (combined data of Singapore, South Korea, Japan and Finland) are shown in Figure 1A. The detailed descriptions for each cluster described in familial contexts are summarized in Table 1. The values are presented in percentage, with the average across all parent-responses as a reference. Each cluster is described in the context of the family and is characterized by its main specificities.

Cluster 1 ($n = 261$) – '*High-all-round activity and screen media-late family*' in relative terms was described by above average screen media and non-screen media use. Parent responses suggested high-screen media and non-screen media engagement including high-physical activity engagement. Cluster 1 was characterized by a lower ownership of video game and CD-DVD players at home, and contrastingly, +78% more than average ownership of intelligent toys (e.g. programming robots, learning codes). Parents in Cluster 1 reported very high-screen media use at +119% above the average during weekdays and weekend. Parent-reported child screen media use on the weekday and weekend was +326% more than the average use. Of interest, the screen media engagement for educational purpose was +693% more than the average for screen media creation. Parents in this cluster also reported +153% more than the average for child non-screen media engagement – for reading physical books (+184% more

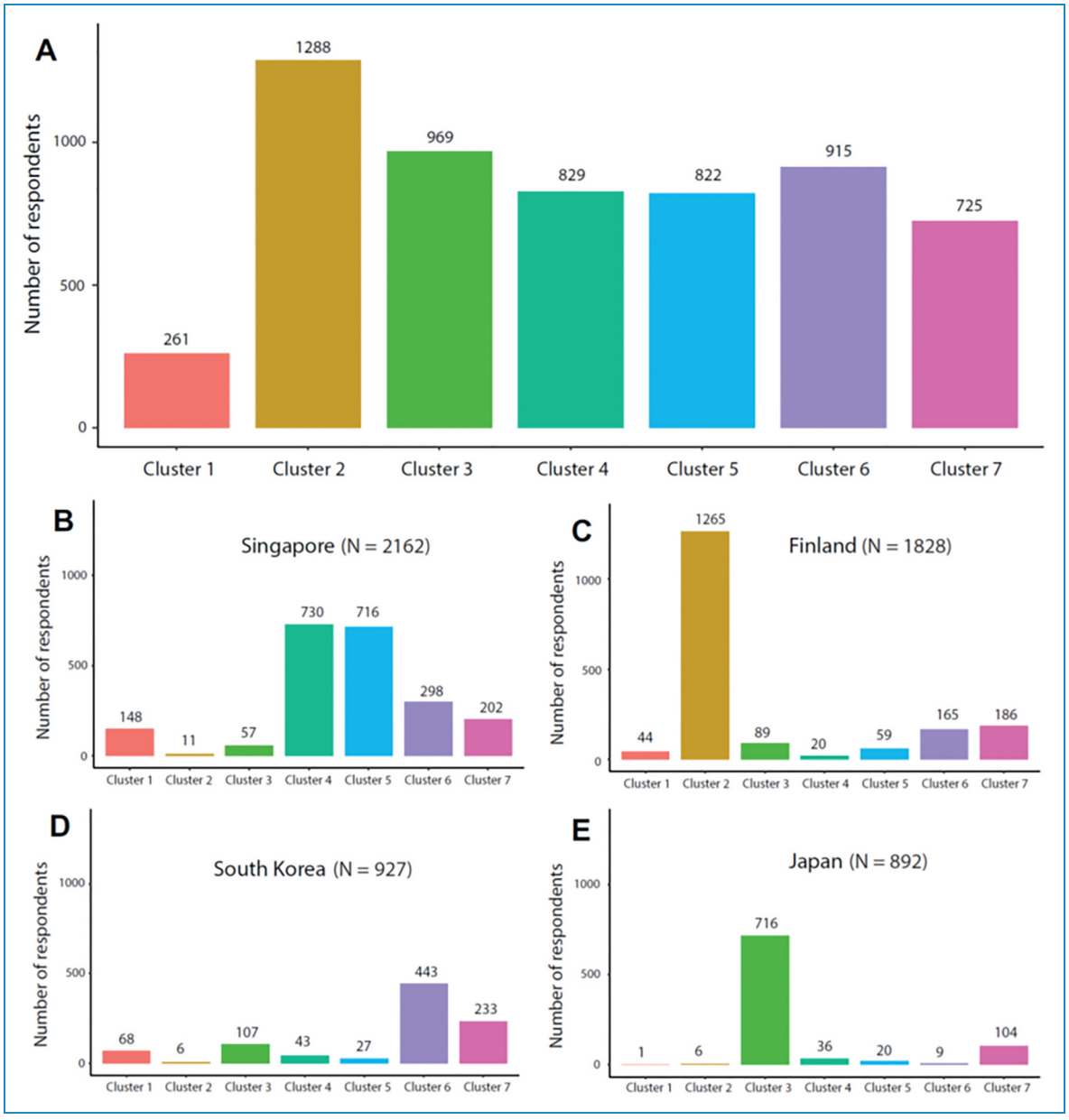

Figure 1. Clusters distribution for the whole data set (1A, $N = 5809$) and breakdown by countries: Singapore (1B, $N = 2162$), Finland (1C, $N = 1828$), South Korea (1D, $N = 927$) and Japan (1E, $N = 892$). All clusters were statistically different from each other. *Note.* Cluster 1: High-all-round activity and screen media-late family, Cluster 2: Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family, Cluster 3: High-screen media-for-entertainment and low-engagement family, Cluster 4: Low all-round activity a high nap-time family, Cluster 5: High-screen media, high-physical activity and high-engagement family, Cluster 6: Screen media-physical activity-engagement hands-off family and Cluster 7: Screen media-lite, screen media-late and high-physical activity family.

than the average), for drawing and painting (+224% more than the average), for physical activity (+39% more than the average) and for outdoor play on weekdays (+181% more than the average). For this reason, the adjectival term *high all-round activity family* is used to partially describe Cluster 1. Parents in this cluster reported that the child's first exposure to screen media was later in childhood (+40% later than average for fixed screens and +20% later than average for mobile screens). Therefore, the adjectival term of *screen media-late family* completed the description of Cluster 1 (i.e. *High-all-round activity and screen media-late family*).

Cluster 2 ($n = 1288$) – *'Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family'* in relative terms was described by a lower average time spent using screen media for parents and children (i.e. *screen media-lite*). In this cluster, the lower-than-average engagement in screen media was also associated with a

Table 1. Descriptive data for each cluster: average and standard deviation for each question of SMALLQ® is accompanied by the percentage difference to the global average (i.e. with the average of all the data as the reference).

		Cluster 1 ($N = 261$)			Cluster 2 ($N = 1288$)			Cluster 3 ($N = 969$)			Cluster 4 ($N = 829$)			Cluster 5 ($N = 822$)			Cluster 6 ($N = 915$)			Cluster 7 ($N = 725$)			Total respondents ($N = 5809$)	
Items	Questions	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Mean	SD
	Child Screen Media and Non-Screen Media Habits																							
Child duration of media use	*On a weekday* Educational learning	**378.47**	1.81	1.89	**−46.67**	0.20	0.32	**−61.45**	0.15	0.36	**−27.27**	0.28	0.47	**25.70**	0.48	0.67	**17.48**	0.44	0.79	**8.78**	0.41	0.77	**0.38**	0.76
	Entertainment	**109.72**	2.63	2.21	**−19.38**	1.01	0.71	**27.13**	1.60	1.37	**−26.96**	0.92	0.90	**23.11**	1.55	1.38	**−2.74**	1.22	1.37	**−33.26**	0.84	0.85	**1.26**	1.26
	Media creation	**782.59**	0.64	1.05	**−21.97**	0.06	0.16	**−74.34**	0.02	0.19	**−42.93**	0.04	0.18	**−37.82**	0.05	0.18	**−23.00**	0.06	0.21	**−22.35**	0.06	0.20	**0.07**	0.31
	Communication	**446.98**	0.65	1.15	**−30.34**	0.08	0.15	**−79.01**	0.03	0.11	**−0.37**	0.12	0.25	**62.71**	0.19	0.30	**−26.46**	0.09	0.21	**−38.70**	0.07	0.17	**0.12**	0.34
	On a weekend day Educational learning	**321.09**	1.67	1.68	**−33.85**	0.26	0.38	**−63.79**	0.14	0.35	**−15.43**	0.34	0.57	**60.17**	0.64	0.91	**−5.31**	0.38	0.61	**−14.06**	0.34	0.52	**0.40**	0.73
	Entertainment	**44.63**	2.52	2.15	**−11.70**	1.54	0.95	**32.97**	2.32	1.66	**−22.83**	1.34	1.31	**29.39**	2.25	1.83	**−9.68**	1.57	1.36	**−34.36**	1.14	0.99	**1.74**	1.48
	Media creation	**692.87**	0.70	1.15	**−12.08**	0.08	0.20	**−72.54**	0.02	0.16	**−42.97**	0.05	0.25	**−9.08**	0.08	0.30	**−37.19**	0.06	0.19	**−24.64**	0.07	0.21	**0.09**	0.35
	Communication	**476.93**	0.84	1.64	**−21.13**	0.12	0.20	**−80.02**	0.03	0.15	**−11.14**	0.13	0.25	**62.76**	0.24	0.49	**−36.53**	0.09	0.21	**−39.51**	0.09	0.22	**0.15**	0.46
	Average percentage difference for this item	**406.66**			**−24.64**			**−46.38**			**−23.74**			**27.12**			**−15.43**			**−24.76**				
	Child's first exposure to digital media (total months) — Fixed screens (television, desktop, computer, etc.)	**40.35**	23.38	15.00	**−51.10**	8.15	9.36	**−21.28**	13.11	12.62	**10.78**	18.45	12.28	**3.22**	17.19	11.11	**46.43**	24.39	14.77	**30.12**	21.67	14.53	**16.66**	13.74
	Mobile screens (smartphone, tablet, handheld gaming device, etc.)	**20.85**	28.67	17.01	**−33.68**	15.74	12.30	**4.72**	24.85	14.34	**−9.56**	21.46	11.99	**−12.23**	20.82	11.13	**34.08**	31.81	15.97	**27.80**	30.32	15.42	**23.73**	14.89
	Average percentage difference for this item	**30.60**			**−42.39**			**−8.28**			**0.61**			**−4.50**			**40.25**			**28.96**				

(continued)

Table 1. Continued.

Items	Questions		Cluster 1 ($N = 261$)			Cluster 2 ($N = 1288$)			Cluster 3 ($N = 969$)			Cluster 4 ($N = 829$)			Cluster 5 ($N = 822$)			Cluster 6 ($N = 915$)			Cluster 7 ($N = 725$)			Total respondents ($N = 5809$)	
			Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Mean	SD
	Child non-digital media use	*On a weekday* Afternoon naps	**85.44**	1.50	1.60	**−35.88**	0.52	0.83	**−60.07**	0.32	0.69	**84.93**	1.50	0.96	**117.52**	1.76	1.27	**−56.54**	0.35	0.68	**−45.74**	0.44	0.78	**0.81**	1.09
		Reading printed books	**184.39**	1.73	1.54	**0.95**	0.61	0.46	**−49.05**	0.31	0.31	**−28.46**	0.43	0.38	**10.55**	0.67	0.55	**5.44**	0.64	0.56	**11.19**	0.67	0.59	**0.61**	0.63
		Drawing, painting, sketching, and other forms of craftwork	**223.38**	2.35	1.97	**−3.22**	0.70	0.61	**−39.30**	0.44	0.41	**−35.91**	0.47	0.45	**−2.85**	0.71	0.61	**19.08**	0.86	0.78	**−1.96**	0.71	0.58	**0.73**	0.80
		Helping with simple household chores	**253.64**	1.13	1.04	**11.07**	0.36	0.32	**−33.76**	0.21	0.20	**−38.30**	0.20	0.22	**−1.20**	0.32	0.29	**−17.22**	0.27	0.25	**1.03**	0.32	0.29	**0.32**	0.39
		Indoor play	**112.44**	3.23	2.51	**41.79**	2.16	1.62	**−60.44**	0.60	0.65	**−24.74**	1.14	1.01	**16.10**	1.77	1.37	**−14.40**	1.30	1.16	**−5.72**	1.43	1.14	**1.52**	1.46
		Outdoor physical play	**164.31**	2.37	2.26	**33.53**	1.20	1.13	**−57.58**	0.38	0.55	**−36.66**	0.57	0.62	**−6.10**	0.84	0.77	**−14.52**	0.77	0.81	**25.42**	1.12	1.04	**0.90**	1.06
		On a weekend day Afternoon naps	**52.90**	1.41	1.33	**−39.71**	0.56	0.82	**−56.00**	0.41	0.69	**84.66**	1.71	0.92	**125.63**	2.08	1.13	**−56.00**	0.41	0.72	**−42.23**	0.53	0.83	**0.92**	1.09
		Reading printed books	**114.99**	1.43	1.06	**12.54**	0.75	0.51	**−47.44**	0.35	0.35	**−26.61**	0.49	0.45	**15.80**	0.77	0.61	**6.61**	0.71	0.64	**3.90**	0.69	0.54	**0.67**	0.60
		Drawing, painting, sketching and other forms of craftwork	**146.79**	2.10	1.48	**7.14**	0.91	0.70	**−35.59**	0.55	0.58	**−33.69**	0.57	0.52	**0.29**	0.86	0.68	**14.29**	0.97	0.77	**2.19**	0.87	0.65	**0.85**	0.78
		Helping with simple household chores	**195.62**	1.13	1.03	**24.38**	0.47	0.40	**−34.30**	0.25	0.25	**−40.74**	0.23	0.26	**3.03**	0.39	0.37	**−20.54**	0.30	0.31	**1.18**	0.39	0.33	**0.38**	0.43
		Indoor play	**58.58**	3.35	2.23	**56.99**	3.32	1.84	**−54.70**	0.96	1.07	**−27.44**	1.53	1.28	**12.37**	2.38	1.69	**−17.89**	1.74	1.44	**−9.29**	1.92	1.44	**2.11**	1.76
		Outdoor physical play	**81.12**	2.87	2.08	**8.29**	1.72	0.96	**−33.24**	1.06	0.95	**−31.28**	1.09	0.97	**0.68**	1.60	1.16	**−7.44**	1.47	1.20	**44.89**	2.30	1.62	**1.59**	1.29
	Average percentage difference for this item		**139.47**			**9.82**			**−46.79**			**−12.85**			**24.32**			**−13.26**			**−1.26**				
	Physical play that makes child breathe faster and harder	Percentage of time child spent on physical play on a weekday	**34.11**	43.85	23.60	**−10.13**	29.39	20.71	**−42.23**	18.89	19.79	**−15.65**	27.58	21.19	**40.90**	46.07	23.82	**−18.91**	26.51	20.17	**57.56**	51.52	25.32	**32.70**	24.34
		Percentage of time child spent on physical play on a weekend day	**24.16**	53.43	25.90	**−22.10**	33.52	20.95	**−28.43**	30.80	23.13	**−5.66**	40.60	23.87	**38.40**	59.56	22.96	**−16.08**	36.11	22.08	**51.80**	65.32	22.28	**43.03**	25.88
	Average percentage difference for this item		**29.13**			**−16.12**			**−35.33**			**−10.65**			**39.65**			**−17.50**			**54.68**				
	Child sleep duration	Nightly sleep on a weekday	**−2.58**	9.35	1.41	**5.00**	10.08	0.77	**0.91**	9.69	0.87	**−6.30**	8.99	1.19	**−4.44**	9.17	1.11	**0.18**	9.62	1.01	**2.83**	9.87	1.00	**9.60**	1.07
		Nightly sleep on a weekend day	**−3.18**	9.57	1.48	**6.63**	10.54	0.92	**0.74**	9.96	1.04	**−6.75**	9.22	1.32	**−2.89**	9.60	1.32	**−1.23**	9.76	1.19	**0.93**	9.98	1.28	**9.88**	1.25
	Average percentage difference for this item		**2.34**			**1.15**			**3.04**			**−9.36**			**−9.64**			**6.95**			**5.92**				
Child general information	Age of child (years)		**5.73**	4.92	1.21	**−3.63**	4.48	1.38	**10.50**	5.14	1.00	**−16.37**	3.89	1.26	**−20.60**	3.69	1.27	**17.02**	5.44	0.89	**10.94**	5.16	1.01	**4.65**	1.32
	Height of child (cm)		**2.97**	110.63	12.90	**−0.54**	106.86	11.30	**1.35**	108.89	10.07	**−4.54**	102.56	13.68	**−6.84**	100.09	14.39	**5.48**	113.33	8.66	**4.11**	111.85	10.48	**107.44**	12.41
	Weight of child (kg)		**8.77**	19.10	6.73	**−1.74**	17.26	7.18	**1.69**	17.86	4.75	**−12.83**	15.31	4.81	**−13.45**	15.20	4.62	**13.31**	19.90	5.28	**10.79**	19.46	6.25	**17.56**	5.98

(continued)

Table 1. Continued.

Items	Questions	Cluster 1 (*N* = 261)			Cluster 2 (*N* = 1288)			Cluster 3 (*N* = 969)			Cluster 4 (*N* = 829)			Cluster 5 (*N* = 822)			Cluster 6 (*N* = 915)			Cluster 7 (*N* = 725)			Total respondents (*N* = 5809)	
		Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Percentage difference to the whole countries	Mean	SD	Mean	SD
–	**Home Digital Environment, Parent Screen Media Habits and Parent Engagement with Child**																							
Digital media device(s) available at home	Television	**−3.78**	93.10	/	**−0.11**	96.66	/	**2.70**	99.38	/	**−0.15**	96.62	/	**0.83**	97.57	/	**−1.85**	94.97	/	**−0.50**	96.28	/	**96.76**	/
	Computer	**−9.51**	73.18	/	**9.25**	88.35	/	**4.51**	84.52	/	**−15.13**	68.64	/	**−8.54**	73.97	/	**2.70**	83.06	/	**4.55**	84.55	/	**80.87**	/
	Mobile devices	**−1.25**	96.93	/	**1.80**	99.92	/	**−0.12**	98.04	/	**−0.95**	97.23	/	**−0.60**	97.57	/	**−0.24**	97.92	/	**−0.51**	97.66	/	**98.16**	/
	Video game devices	**−33.35**	23.37	/	**70.48**	59.78	/	**49.80**	52.53	/	**−44.96**	19.30	/	**−24.72**	26.40	/	**−62.29**	13.22	/	**−21.72**	27.45	/	**35.07**	/
	Blu-ray/DVD/CD/videotape players	**−43.25**	26.44	/	**36.84**	63.74	/	**80.55**	84.11	/	**−60.64**	18.34	/	**−57.43**	19.83	/	**−31.73**	31.80	/	**16.96**	54.48	/	**46.58**	/
	Intelligent/technology toys	**78.05**	21.46	/	**9.53**	13.20	/	**−50.33**	5.99	/	**5.11**	12.67	/	**49.41**	18.00	/	**−24.72**	9.07	/	**−8.43**	11.03	/	**12.05**	/
	Average percentage difference for this item	**−2.18**			**21.30**			**14.52**			**−19.45**			**−6.84**			**−19.69**			**−1.61**				
Parent duration of media use	*On a weekday* Work	**48.00**	4.74	3.76	**−6.19**	3.00	2.84	**−38.41**	1.97	2.70	**20.73**	3.86	3.48	**55.72**	4.98	3.42	**−7.13**	2.97	3.26	**−32.83**	2.15	2.87	**3.20**	3.28
	Entertainment	**83.94**	2.54	2.03	**−2.85**	1.34	1.02	**14.50**	1.58	1.32	**−10.58**	1.23	1.07	**39.47**	1.93	1.41	**−35.76**	0.89	0.99	**−32.06**	0.94	0.92	**1.38**	1.26
	Social networking	**134.58**	2.69	2.63	**−3.54**	1.11	0.87	**−48.96**	0.59	0.71	**−20.55**	0.91	0.97	**57.02**	1.80	1.82	**3.35**	1.19	1.32	**−22.10**	0.89	1.04	**1.15**	1.35
	Personal development	**161.55**	2.18	1.99	**−16.90**	0.69	0.99	**−31.53**	0.57	0.60	**−24.54**	0.63	0.61	**36.43**	1.14	1.04	**8.38**	0.90	1.04	**−9.82**	0.75	0.91	**0.83**	1.03
	On a weekend day Work	**197.68**	1.42	2.06	**−59.88**	0.19	0.42	**−12.89**	0.42	0.93	**20.74**	0.58	1.10	**84.51**	0.88	1.40	**−25.69**	0.35	0.74	**−34.66**	0.31	0.66	**0.48**	1.02
	Entertainment	**65.74**	3.12	2.44	**1.45**	1.91	1.21	**8.64**	2.04	1.67	**−13.33**	1.63	1.39	**55.30**	2.92	1.96	**−36.41**	1.20	1.33	**−39.31**	1.14	1.12	**1.88**	1.64
	Social networking	**110.06**	2.53	2.42	**7.67**	1.30	0.96	**−49.83**	0.60	0.76	**−15.08**	1.02	0.99	**73.67**	2.09	1.93	**−14.87**	1.02	1.07	**−34.18**	0.79	0.99	**1.20**	1.35
	Personal development	**149.10**	1.77	2.03	**−24.44**	0.54	0.71	**−17.89**	0.58	0.65	**−17.32**	0.59	0.63	**60.63**	1.14	1.12	**−6.80**	0.66	0.79	**−26.70**	0.52	0.65	**0.71**	0.92
	Average percentage difference for this item	**118.83**			**−13.08**			**−22.05**			**−7.49**			**57.84**			**−14.37**			**−28.96**				
Shared media usage between parent and child	Percentage of time parent engaged with child on a weekday	**7.74**	42.30	27.43	**5.96**	41.60	29.65	**−3.15**	38.03	31.03	**−43.78**	22.07	22.28	**41.06**	55.38	28.54	**−41.67**	22.90	22.25	**46.91**	57.68	31.08	**39.26**	30.64
	Percentage of time parent engaged with child on a weekend day	**8.37**	50.50	29.06	**0.50**	46.83	28.40	**−5.95**	43.83	30.35	**−33.76**	30.87	25.71	**36.00**	63.38	26.13	**−30.86**	32.22	25.31	**40.78**	65.60	28.49	**46.60**	30.29
	Average percentage difference for this item	**8.05**			**3.23**			**−4.55**			**−38.77**			**38.53**			**−36.26**			**43.85**				
Engaging physical play with child	Percentage of time parent engaged with child in physical play on a weekday	**22.96**	37.45	24.52	**−9.46**	27.58	25.69	**−39.85**	18.32	22.86	**−19.82**	24.42	22.77	**55.79**	47.45	28.72	**−36.65**	19.30	17.67	**67.48**	51.01	29.04	**30.46**	27.42
	Percentage of time parent engaged with child in physical play on a weekend day	**14.46**	56.23	27.04	**−15.66**	41.43	27.59	**−27.66**	35.54	28.11	**−4.94**	46.69	28.23	**41.21**	69.37	24.19	**−24.70**	36.99	25.02	**49.67**	73.52	21.66	**49.12**	29.82
	Average percentage difference for this item	**18.71**			**−12.56**			**−33.75**			**−12.38**			**48.50**			**−30.68**			**58.58**				
Parent age	Age of parent (years)	**−1.09**	35.85	5.71	**−1.40**	35.74	5.27	**3.75**	37.60	4.96	**−4.78**	34.51	6.82	**−4.79**	34.51	5.65	**5.57**	38.26	4.96	**1.72**	36.87	4.59	**36.24**	5.59

Note. Child screen media use for educational learning (e.g. reading digital e-book, learning math via educational apps), child screen media use for entertainment (e.g. watching movies, clips, playing games, listening to music), child screen media use for media creation (e.g. programming robots/interactive toys), child screen media use for communication (e.g. video-chatting with grandparents).

less-than-average level of physical activity of moderate-to-vigorous intensity (i.e., *moderate-to-vigorous physical activity-lite*) More precisely, parents in this cluster reported a high use of video games (+70% more than the average) and CD-DVD player ownership at home (+37% more than the average). However, parents in this cluster reported less engagement with screen media (−16% less than the average with −60% use than the average for work). Parents in this cluster reported an earlier child first-exposure to screen media (−42% less compared to the average age of first exposure) (i.e. *Early-screen media*), however child screen media engagement was lower (−20% lower regardless the type of usage), and specifically, lower for education use (−46% lower compared to the average) (i.e. *screen media-lite*). Parents in this cluster reported higher non-screen media behaviour (+16% more than the average regardless the activity) except in those children who had spent less time napping (−37% less compared to the average time of napping). Interestingly, in the cluster, the percentage of child physical activity that was accompanied by parents was lower (−14% lower compared to the average). For these reasons, Cluster 2 was named adjectivally as '*Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family'*

Cluster 3 ($n = 969$) – *'High-screen-media-for-entertainment and low-engagement family'*: In this cluster both parents and children used screen media predominantly for entertainment (+21% more compared to the average) (i.e. *high-screen media for entertainment*) and less for other purposes. Parents and children used less screen media for work, social networking and for personal development (−31% less for parents and −71% less for children compared to the average). Somewhat similar, to Cluster 2, there was a high ownership of video games (+49% more than the average) and CD-DVD player in the home (+80% more than the average) but relatively less in the ownership of intelligent toys (−50% less compared to the average). Parents and children in this cluster spent less time on non-screen media activities (−46% less compared to the average) and also spent less time engaged in parent–child activities (−35% less compared to the average) (i.e. *low engagement*). For these reasons, Cluster 3 is adjectivally named as the '*High-screen media-for-entertainment and low-engagement family'*.

Cluster 4 ($n = 829$) – *'Low all-round activity and high nap-time family*': This cluster was characterized by the lowest screen and non-screen media behaviours (i.e. *low all-round activity*) In contrast to Cluster 3, there was less ownership of screen media in the home (−19% less compared to the average) and specifically less video game players (−45% less compared to the average) and CD-DVD players (−61% less compared to the average). Also, except for parents' use of screen media for work (+20% more than the average), parents and children, respectively in this cluster had less screen media use (−17% less compared to the average for parents and −24% less compared to the average for children), and also for non-screen media activity (−33% less compared to the average for children). Children in this cluster had a longer nap time (+85% more than the average) (i.e. *high nap time*) perhaps because children were younger in age in this cluster (−16% younger compared to the average). For these reasons, Cluster 3 is adjectivally named as the '*Low all-round activity and high nap-time family'*.

Cluster 5 ($n = 822$) – *'High-screen media, high-physical activity and high engagement family'*: In this cluster, parents and children, on their own, had higher screen media engagement (+57% higher compared to the average for parents and +27% higher compared to the average for children) (i.e. *high-screen media, high-engagement*) with a higher parent–child screen media engagement (+39% more compared to the average). Children in this cluster spent more time engaged in indoor and outdoor physical activity (+39% more compared to the average) (i.e. *high-physical activity, high-engagement*) and also shared more time with parents in indoor and outdoor physical activity (+48% more compared to the average). Younger children (−20% younger compared to the average) in this cluster spent more time napping (+121% more compared to the average) and also more time on other non-screen media activities. For these reasons, Cluster 5 was names as the '*High-screen media, high-physical activity and high engagement family*'.

Cluster 6 ($n = 915$) – *'Screen media-physical activity-engagement hands-off family'*: This cluster was characterized by a lower child screen media use (−20% lower compared to the average) except for education (+17% more compared to the average). Children in this cluster were first exposed to screen media later (+39% older than the average) (i.e. *Screen media hands-off*). In this cluster home ownership of screen media types was lower especially for CD-DVD (−31% lower compared to the average), video games (−62% lower compared to the average) and intelligent toys (−24% lower compared to the average). Parents in this cluster used less of screen media (−21% less compared to average) except for social networking and personal development. Parent–child times shared for using screen media and physical activity, respectively were lower (−36% lower digital media use compared to the average and −31% lower physical activity compared to the average) (i.e. *Physical activity and engagement hands-off*). Children in this cluster napped less (−56% less compared to the average) and were older (+17% older than the average) and spent less time on indoor/outdoor physical activity (−11% less compared to the average), with a lower physical activity intensity (−17% less compared to the average). For these reasons, Cluster 6 was adjectivally named as the '*Screen media-physical activity-engagement hands-off family*'.

Cluster 7 ($n = 725$) – '*Screen media-lite, screen media-late and high-physical activity family*': In this cluster parents reported a lower usage of digital media for all purposes (−28% less compared to the average), and concomitantly, lower child screen media engagement (−29% less compared to the average), except for educational purpose (+8% more compared to the average) (i.e. *Screen media-lite*) Children in this cluster were first exposed to screen media later (+29% older than the average) (i.e. *Screen media-late*). Parent–child shared times for screen media use and indoor and outdoor physical activity, respectively, were high (+43% more compared to the average for digital media use, and +59% more compared to the average for physical activity). Children in this cluster had higher outdoor physical activity time (+35% more compared to the average) and engaged in more intense indoor and outdoor physical activity (+55% more compared to the average) (i.e. *high-physical activity*). For these reasons, Cluster 7 was adjectivally named as the '*Screen media-lite, screen media-late and high-physical activity family'*.

Discussion

Clustering of the combined datasets of parent responses from Singapore, South Korea, Japan and Finland

The main purpose of the study was to distill and explain the characteristics of time-use of parents and children derived from the online SMALLQ® for Singapore, South Korea, Japan and Finland, using machine learning and an unsupervised clustering approach. The four countries were adjudged as high-income and were high-human development-index countries. A key finding was the identification of seven clusters that characterised the diversity of parent responses about the digital and non-digital media habits of preschool children. Understanding the characteristics of each cluster allow researchers to better appreciate the complexities of human behaviour activity of parents and preschool children in relation to physical activity, sedentary time and sleep, and the home environment. Our research approach is supported by a review of the use of unsupervised human activity recognition that showed that its use and its utility is gaining traction in health care, especially in the activities of daily living at home and in improving the quality of life of people's lives.[12]

Distinctive cluster diversity

The present results revealed the diversity of clusters that characterised the combined country-data of parent-reported digital and non-digital media time-use and habits of preschool children. For instance, the *Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family* (i.e. Cluster 2, highest number, $n = 1288$) and the *High-all-round activity and screen media-late family* (i.e. Cluster 1, lowest number, $n = 261$), respectively, represented 24.3% and 4.9% of the full dataset. Relatively moderate numbers of parents were grouped, respectively in the *High-screen media-for-entertainment and low-engagement family* (Cluster 3, moderate number, $n = 969$) and *Screen media-physical activity-engagement hands-off family* (Cluster 6, moderate number, $n = 916$). The remaining clusters were those with low number of parents and these were the *Low all-round activity and high nap-time family* (Cluster 4, low number, $n = 829$), the *High-screen media, high-physical activity and high engagement family'* (Cluster 5, low number, $n = 822$) and the *Screen media-lite, screen media-late and high-physical activity family* (Cluster 7, low number, $n = 725$). The diversity of cluster profiles across the four countries suggested that screen time, physical activity and sleep behaviours among preschool children, and parenting behaviours (e.g. whether parents engaged with their children when the latter are using screen media) are wicked problems with no distinctive 'right' or 'wrong' answers but rather degree of 'health-enabling' or 'health-distressing' responses in human behaviour.[32] For instance, our results showed that profiles with high levels of physical activity were not necessarily associated with lower screen time and vice versa, and this suggested the need to work on all potential moderators of sedentary and physical activity behaviours in order to increase compliance to the WHO Movement Guidelines.[7] Wicked problems are therefore resistant to simplistic solutions and require further research, resolve, resources, and time to address. Simply explained, wicked problems arise where there is a lack of consensus on problem definition, combined with a lack of consensus on solutions.[33] It is instructive that Termeer and his colleagues opined that wicked problems have no solutions in terms of definitive and objective answers.[34]

Unique observations across the clusters

From Table 1, seven noteworthy cluster observations are made – (i) Cluster 1 (*High-all-round activity and screen media-late family)*, revealed that it is possible for high-screen media use (hence contributing to sedentary behaviour) to co-exist with high levels of physical activity in preschool children over a 24-hour period. Such a paradoxical habits were documented in other studies, albeit in older children and adolescents.[35] The cited authors reported that there was a more pronounced decline for girls for meeting either physical activity or sedentary behaviour guidelines with age and that interventions to ameliorate such trends should start early in age, (ii) Children playing video games were predominantly found in Clusters 2 and 3, which are seemingly well represented in Finland[36] and Japan (https://www.nippon.com/en/in-depth/a04103/).[37]

This plausibly could be explained by the strong gaming cultures in these two countries but more research in this area is recommended to verify this explanation is tenable, (iii) Not surprising is the finding that high parental digital media use also translated to high child digital media use and time spent together engaged in screen media activities (i.e. Clusters 1 and 5), (iv) It appears that a child's first exposure to screen media did not make much of an impact (i.e. as this parent-report data is present in all the clusters), (v) Child digital media use is not homogenous – it is used extensively for entertainment (i.e. Cluster 3) and for education (i.e. Cluster 1), with the magnitude of use in favour of Cluster 3, where the use of screen media for entertainment was 371% that for educational purposes. This observation of greater screen engagement for entertainment than for education among young children is supported by research reported elsewhere[38] and in our recent research that was based on a different set of data collected in 2018,[15] and (vi) Children's sleep did not seem to be a strong discriminant factor between the clusters (i.e. average from all clusters were very close to the global average). Apart from Cluster 2 (which is the major profile for Finland), where children's average daily sleep was above 10 hours, average sleep of less than 10 hours (i.e. below the WHO guideline of 10–13 hours) was spread out among the other clusters. Even then, Finland contributed 69.2% of the sleep data in Cluster 2, which meant that there were strong within-country differences in children's sleep, with 30.8% of parents from Finland reporting daily sleep of less than 10 hours for preschool children, plausibly among the older preschool children, an average that is lower than the recommended 10 to 13 hours of good quality night-time sleep for children aged between 2 and 5 years. Children form Singapore, South Korea and Japan predominantly had less sleep than children from Finland. These findings have resonance with comparative sleep-based research on preschool children among several Asian and European countries. For example, in a combined 2590 sample of preschool children from pre-dominantly Asian and predominantly Caucasian countries, the preschool children in former group of countries had significantly later bedtimes, shorter night-time sleep, and increased parental perception of sleep problems compared to preschool children from the latter group of countries.[39]

Clusters represented within each of the countries

From Figure 1, the clusters that best described parent responses to the SMALLQ® offer interesting insights. For instance, Finland is mostly represented by Cluster 2, labelled in this study as the *Early-screen media, screen media-lite and moderate-to-vigorous physical activity-lite family* and making up 98.2% of the 4-country pooled dataset. Japan is mostly represented by Cluster 3 or the *High-screen media-for-entertainment and low-engagement family*, with parents in this cluster making up 73.9% of the pooled dataset. In the Finland example, it is conceivable that as preschool children were introduced to screen media earlier than the pooled average, they also had less than the pooled average of moderate-to-vigorous physical activity since as the former daily habit gets more entrenched (see Table 1). To the authors' knowledge, there are apparently no published researches on preschool children's time use using clustering techniques in the literature, and this precludes direct comparisons across studies. Nonetheless, our findings compare indirectly against the findings on 736 Finnish preschool children where increased screen time was associated with later bedtimes and shorter sleep duration.[40] In another Finnish study from 2011 to 2017 involving 699 children of age 5 years, the authors reported that high-dose electronic screen media use has multiple risks for children's longer-term socio-emotional development and well-being.[41] Comparative findings for Japan (*High-screen media-for-entertainment and low-engagement family*) include findings on 421 preschool children reported by Kim and his colleagues.[42] They showed that children who failed to meet all the 24-hour Movement Guidelines have a higher probability of overweight or obesity than those who met all the guidelines. In a Japanese study on age-matched preschool children with and without autism spectrum disorder (ASD), higher levels of physical activity in the morning and in the afternoon enabled better sleep for children with ASD.[43]

Parents in South Korea were best represented by Clusters 6 and 7, that is a combination of *Screen media-physical activity-engagement hands-off family* and *Screen media-lite, screen media-late and high-physical activity family*. Research showed that in 400 children aged 2 to 5 years followed up over 2 years, ownership and access to tablets increased significantly, from 48% to 65% over a 2-year period with that of mobile phones remaining high at 91–98%. The study also revealed that children spent more time on screen viewing for TV, and tablets on the weekend than on the weekday, with mobile phone use remaining the same at 0.4 hours per day.[44] Another South Korean study on 1775 children aged 0 to 5 years showed that compared to children who participated in physical activity for less than 1 hour per week, those who participated in physical activity for 1 hour to less than 3 hours per week were more likely to show high emotional skills. The same results were obtained for reading but not for TV-viewing.[45]

Among the four countries, Singapore was represented by four distinct clusters, namely Clusters 4 and 5 (*Low all-round activity and high nap-time family* and *High-screen media, high-physical activity and high-engagement family*), followed by Clusters 6 and 7 (*Screen media-physical activity-engagement hands-off family* and *Screen media-lite, media-late and high-physical activity family*). The former clusters represented 89.0% and 87.1%,

respectively of the pooled dataset, whereas the latter clusters represented 32.6% and 32.1%, respectively of the pooled dataset.

Relative to the other three countries, Singapore had the greatest diversity in terms of culture and ethnicity (Chinese, Malay, Indian and mixed) whereas the other three countries had a more homogenous population and culture (Japanese, Finnish or Korean), and this might plausibly explain the greater number of clusters for the Singapore cohort that characterized the parent responses to the SMALLQ®. Indeed, in the present Singapore dataset (not shown in the results), there were significant differences among the ethnic groups in terms of daily indoor and outdoor play) and screen media use, especially for education and for entertainment. It appeared that culture and societal influences affected parental attitudes and beliefs about children's physical activity and screen media engagement, which might impede or promote children's consumption of physical activity or screen time.[46]

Cluster visualizations

In simplifying and capturing the essence of the unique characteristics of each cluster, the authors visualized that Cluster 1 represented learning-oriented families where parents strongly supported children's development. Cluster 2 appears to include families who believed in the "power of playing" as screen media was used mostly for 'playing' (i.e. entertainment) and children's physical play was unaccompanied by parents and was of light intensity. Cluster 3 encompassed families where children's screen media use was largely unaccompanied by caregivers. Cluster 4 comprised families with younger children whose lifestyle habits were still 'under construction'. The buzzword for Cluster 5 is family centeredness where activities were done together as a family. Cluster 6 is interesting because it seemed that the focus and interest were different from others (low engagement in both screen media and physical activity). Perhaps, they were represented by families with different sets of values. And finally, Cluster 7 comprised of families with physical activity-infused lifestyles (i.e. where children got support and learning was geared towards physical activities). As the above are visualizations of the clusters, the authors encourage further research to better explain the varied familial contexts for positive child development.

Strengths and limitations

The data were collected using a content-validated and reliable SMALLQ® that were translated to specific languages for use in each country. The research has several strengths in that it involved a large dataset of parent-reported daily screen media and non-screen media habits of preschool children across the four high-income and high-human-development index-countries, where the data were treated with an unsupervised clustering technique. The identified clusters revealed a plethora of daily parent and child behaviour characteristics on that were distinctively unique from each other. These within and across country screen media and non-screen media characteristics of parents and preschool children provide useful insights that can inform future research or more targeted and nuanced parent education interventions. Like all research, there were several limitations – the SMALLQ® is a parent self-report and recall questionnaire, therefore the tool may be prone to self-report bias, social desirability bias and recall bias.[47] However, mitigation strategies such as keeping the online questionnaire anonymous, appropriate questionnaire development, and keeping behaviour recall to the last seven days, helped to minimise the limitations. Additionally, as the pooled data consisted of a high proportion of at least college-level educated parents (data not shown) and using such an online questionnaire to collect data was considered as an effective means of collecting self-reported information in health-rated research.[48] As the research was conducted between 15 March and 1 December, some of the differences in daily screen media and non-screen media habits of parents and children across the countries may be attributed to the seasonality of climate across countries. The study does not address seasonal differences in preschool children's screen media and non-screen media habits. In Finland, data were collected during the transition between autumn and winter; in Japan and South Korea, data were collected during autumn; and in Singapore, the data were collected March and September where the weather is tropical. The cross-sectional nature of the research also meant that the results are descriptive and expansive without any cause-or-effect attributions, and finally, since the four countries polled are high-income and high-human development-index countries and the convenience samples are drawn from parents living in urban cities, generalisations cannot be made outside of these contexts.

Conclusions

The clustering approach used to analyse the pooled datasets of time-use of screen and non-screen media behaviours of parents and children living in urban cities and other populated municipalities across Singapore, South Korea, Japan, and Finland produced novel and useful insights that these human activities of daily living can be grouped into seven distinctive clusters. Three key observations were instructive: (i) There were complex connections among the daily behaviours of physical activity, sedentary screen time and sleep among preschool children, parental and home factors, and there appeared to be no 'perfect cluster' of lifestyle behaviours, (ii) it appeared that differences within a country in terms of number of clusters identified (e.g. Singapore) were more apparent than the differences between countries (e.g. Singapore versus Finland), and (iii) taken together, the results of clustering

suggested that it might be more useful for interventions to improve and safeguard the wellbeing and health of children that are targeted according to the characteristics of the predominant clusters within each country.

Acknowledgements: We would like to thank parents of preschool children for their participation in this study. SMALLQ® is trademarked under Class 41 TM120494, c/o Professor Michael Chia, National Institute of Education, Nanyang Technological University, Singapore.

Contributorship: MC, JK, and TC conceived the study and/ or contributed to the overall planning and design of the study. MC & TC collected the data. MC and JK drafted the full original manuscript. TC prepared the manuscript in the journal's format for submission. JK performed the data analyses and interpretation. LYT was involved in the design of the study and critically reviewed the manuscript. JHK and KH co-curated the planning of the study methodology and data collection in South Korea and critically reviewed the manuscript. HK and JM co-curated the planning of the study methodology and data collection in Japan and critically reviewed the manuscript. HV and AS co-curated the planning of the study methodology and data collection in Finland and critically reviewed the manuscript. All authors read and approved the final manuscript.

Declaration of conflicting interests: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval: The human ethics committee of Nanyang Technological University approved this study (NTU IRB 2017-09-036 and IRB 2019-02-036).

Funding: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Ministry of Education, Singapore, Finland Ministry of Education and Culture (grant number OER 29/19 MCYH, OKM/15/626/2019).

This international research is funded by Singapore Ministry of Education (MOE) under the Education Research Funding Programme (OER 29/19 MCYH) and administered by National Institute of Education, Nanyang Technological University, Singapore. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Singapore MOE and NIE. The Finnish Ministry of Education and Culture (grant number OKM/15/626/2019) has funded data collection in Finland. The funding sources are not involved with how the data was collected, analysed, and interpreted, as well as in the preparation of manuscript.

Guarantor: MC

ORCID iD: Terence Chua https://orcid.org/0000-0001-8478-9683

References

1. Tierney AL and Nelson CAIII. Brain development and the role of experience in the early years. *Zero Three* 2009; 30: 9–13.
2. Duncan GJ, Yeung WJ, Brooks-Gunn J, et al. How much does childhood poverty affect the life chances of children? *Am Sociol Rev* 1998; 63: 406–423.
3. Cohen S, Janicki-Deverts D, Chen E, et al. Childhood socioeconomic status and adult health. *Ann N Y Acad Sci* 2010; 1186: 37–55.
4. Evans GW and Cassells RC. Childhood poverty, cumulative risk exposure, and mental health in emerging adults. *Clin Psychol Sci* 2014; 2: 287–296.
5. Bickham DS, Blood EA, Walls CE, et al. Characteristics of screen media use associated with higher BMI in young adolescents. *Pediatrics* 2013; 131: 935–941.
6. Chia M, Tay LY and Chua TBK. The development of an online surveillance of digital media use in early childhood questionnaire-SMALLQ™-for Singapore. *Monten J Sports Sci Med* 2019; 8: 77–80.
7. World Health O. *Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age*. Geneva: World Health Organization, 2019.
8. Guan H, Zhang Z, Wang B, et al. Proportion of kindergarten children meeting the WHO guidelines on physical activity, sedentary behaviour and sleep and associations with adiposity in urban Beijing. *BMC Pediatr* 2020; 20: 70.
9. Jago R, Stamatakis E, Gama A, et al. Parent and child screen-viewing time and home media environment. *Am J Prev Med* 2012; 43: 150–158.
10. Rek M and Kovačič A. Media and preschool children: the role of parents as role models and educators. *Medijske Studije* 2018; 9: 27–43.
11. Alashwal H, El Halaby M, Crouse JJ, et al. The application of unsupervised clustering methods to Alzheimer's disease. *Front Comput Neurosci* 2019; 13: 31.
12. Ariza Colpas P, Vicario E, De-La-Hoz-Franco E, et al. Unsupervised human activity recognition using the clustering approach: a review. *Sensors* 2020; 20: 2702.
13. D'Souza NJ, Downing K, Abbott G, et al. A comparison of children's diet and movement behaviour patterns derived from three unsupervised multivariate methods. *PLOS ONE* 2021; 16: e0255203.
14. van Rooden SM, Heiser WJ, Kok JN, et al. The identification of Parkinson's disease subtypes using cluster analysis: a systematic review. *Mov Disord* 2010; 25: 969–978.
15. Tay LY, Aiyoob TB, Chua TBK, et al. Pre-schoolers' use of technology and digital media in Singapore: entertainment indulgence and/or learning engagement? *EMI Educ Media Int* 2021; 58: 1–20.
16. O'Connor TM, Hingle M, Chuang R-J, et al. Conceptual understanding of screen Media parenting: report of a working group. *Childhood Obesity* 2013; 9: S-110-S-118.
17. Artino AR, La Rochelle JS, Dezee KJ, et al. Developing questionnaires for educational research: AMEE Guide No. 87. *Med Teach* 2014; 36: 463–474.
18. Yusoff MSB. ABC of content validation and content validity index calculation. *Educ Resour* 2019; 11: 49–54.

19. Tavakol M and Dennick R. Making sense of Cronbach's alpha. *Int J Med Educ* 2011; 2: 53–55.
20. World Health Organisation. *Process of translation and adaptation of instruments*. 2016. https://www.mhinnovation.net/sites/default/files/files/WHO%20Guidelines%20on%20Translation%20and%20Adaptation%20of%20Instruments.docx (accessed 11 November 2022).
21. Office UNHD. *Human development index ranking*. United Nations Development Program, Human Development Report. https://hdr.undp.org/data-center/country-insights#/ranks (accessed 11 November 2022). 2020.
22. World Bank. World Bank country and lending groups. The World Bank. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519–world-bank-country-and-lending-groups (2020, accessed 12 October 2021).
23. Chia M, Tay LY and Chua TBK. Quality of life and meeting 24-h WHO guidelines among preschool children in Singapore. *Early Child Educ J* 2020; 48: 313–323.
24. Hasanen E, Koivukoski H, Kortelainen L, et al. Sociodemographic correlates of parental co-participation in digital media use and physical play of preschool-age children. *Int J Environ Res Public Health* 2021; 18: 5903.
25. Guo H, Ma J, Chua TBK, et al. Associations between parents' digital Media habits, engagement, awareness, and movement guidelines among preschool-age children: international ipreschooler surveillance study. *Int J Environ Res Public Health* 2022; 19: 10484.
26. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. 2019. https://www.R-project.org/ (accessed 11 November 2022).
27. Stekhoven DJ. *missForest: nonparametric missing value imputation using random forest R package version 1.4*. 2013. https://cran.r-project.org/web/packages/missForest/missForest.pdf (accessed 11 November 2022).
28. Huang Z. Extensions to the k-means algorithm for clustering large data sets with categorical values. *Data Min Knowl Discov* 1998; 2: 283–304.
29. Szepannek G. Clustmixtype: user-friendly clustering of mixed-type data in R. *R J* 2018; 10: 200.
30. Milligan GW and Cooper MC. An examination of procedures for determining the number of clusters in a data set. *Psychometrika* 1985; 50: 159–179.
31. McClain JO and Rao VR. CLUSTISZ: a program to test for the quality of clustering of a set of objects. *J Mark Res* 1975; 12: 456–460.
32. Rittel HWJ and Webber MM. Dilemmas in a general theory of planning. *Policy Sci* 1973; 4: 155–169.
33. Roberts N. Wicked problems and network approaches to resolution. *Int Public Manag Rev* 2000; 1: 1–19.
34. Termeer CJAM, Dewulf A and Biesbroek R. A critical assessment of the wicked problem concept: relevance and usefulness for policy science and practice. *Policy Soc* 2019; 38: 167–179.
35. Chen S-T, Liu Y, Hong J-T, et al. Co-existence of physical activity and sedentary behavior among children and adolescents in Shanghai, China: do gender and age matter? *BMC Public Health* 2018; 18: 1287.
36. Finland S. *Leisure participation. Digital gaming 2017, 1. Playing digital games has quadruplicated in 25 years*, http://www.stat.fi/til/vpa/2017/02/vpa_2017_02_2019-01-31_kat_001_fi.html (2017, accessed 25 October 2021).
37. Hisakazu H. Video games: a winning strategy for Japan, https://www.nippon.com/en/in-depth/a04103/ (2015, accessed 23 November 2021).
38. Canadian Paediatric Society DHTF, Ottawa, Ontario. Screen time and young children: promoting health and development in a digital world. *Paediatr Child Health* 2017; 22: 461–468.
39. Mindell JA, Sadeh A, Kwon R, et al. Cross-cultural differences in the sleep of preschool children. *Sleep Med* 2013; 14: 1283–1289.
40. Hiltunen P, Leppänen MH, Ray C, et al. Relationship between screen time and sleep among Finnish preschool children: results from the DAGIS study. *Sleep Med* 2021; 77: 75–81.
41. Niiranen J, Kiviruusu O, Vornanen R, et al. High-dose electronic media use in five-year-olds and its association with their psychosocial symptoms: a cohort study. *BMJ Open* 2021; 11: e040848.
42. Kim H, Ma J, Harada K, et al. Associations between adherence to combinations of 24-h movement guidelines and overweight and obesity in Japanese preschool children. *Int J Environ Res Public Health* 2020; 17: 9320.
43. Tatsumi Y, Mohri I, Shimizu S, et al. Daytime physical activity and sleep in pre-schoolers with developmental disorders. *J Paediatr Child Health* 2015; 51: 396–402.
44. Lee DY, Roh HW, Kim S-J, et al. Trends in digital media use in Korean preschool children. *JKMS* 2019; 34: –0.
45. Lee EY and Carson V. Physical activity, sedentary behaviour, and psychosocial well-being among young South Korean children. *Child Care Health Dev* 2018; 44: 108–116.
46. Hesketh KD, Hinkley T and Campbell KJ. Children's physical activity and screen time: qualitative comparison of views of parents of infants and preschool children. *Int J Behav Nutr Phys Act* 2012; 9: 52.
47. Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. *J Multidiscip Healthc* 2016; 9: 211–217.
48. Palmer L, Johnston SS, Rousculp MD, et al. Agreement between internet-based self- and proxy-reported health care resource utilization and administrative health care claims. *Value Health* 2012; 15: 458–465.