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Digital engagement and its association with adverse psychiatric symptoms: A longitudinal cohort study utilizing latent class analysis

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ABSTRACT

Objectives: To assess the impact of digital media usage on psychiatric symptoms in an adolescent population utilizing a longitudinal cohort design.
Methods: Using two waves of the GUI child cohort, age 13 (N = 7527) and age 17/18 (N = 6126), we used latent class analysis (LCA) to create latent groups centred around self-reported time spent online, and the self-reported behaviours children engaged with online. At both waves, the 4 class latent model suited best. We used the different symptoms scales of the Strengths and Difficulties Questionnaires (SDQ), self-reported, at age 17 as our outcome variable. Using linear regression analysis, we then examined the associations between our latent class model and psychiatric symptoms, using moderate usage as our reference group, with adjustments being made for baseline psychiatric symptoms, maternal education and pre-diagnosed mental disorder.
Results: For females, placement in the high usage group at 13 was associated with increased internalizing symptoms, whereas placement in the high usage group at 17 was associated with an increase in all symptoms. For males, placement in the high usage group at 17 was associated with increased emotional symptoms, and placement in the "low usage & behaviour engagement"group, a group showing low reported time online and low engagement in our measured online behaviours at 17, was associated with an increase in all symptoms. Finally for both sexes, placement in the "moderate usage, entertainment only" group at age 13, (a group reporting no school-based online engagement), was associated with increases in all symptoms except emotional symptoms.
Conclusion: High digital media usage is associated with increased psychiatric symptoms in both males and females, with moderate usage associated with positive effects on symptoms compared to both our high usage, and low usage groups.

1. Introduction

Major depressive disorder and anxiety disorder were the 5th and 9th highest causes of years lived with disability according to the global burden of disease in 2016 (Vos et al., 2017). In the last 20 years there has been a rapid increase in rates of mental health problems among teenagers and young adults (Collishaw, 2015; Dorling, 2009; Twenge et al., 2018). Given this recent increase in prevalence (Twenge et al., 2018), identifying potential risk factors is vital in informing preventative or remedial health policies. One potential risk factor for these rises in mental health issues is the use of digital devices, such as PC's and smartphones, as well as online activity including engagement with social media (Dienlin & Johannes, 2020; Odgers & Jensen, 2020). The investigation of digital media engagement in childhood and adolescence and its association with psychiatric symptoms, is a relatively new area of research starting largely with those born from 1990 on. While results are mixed, the growth of digital media, inclusive of social media, gaming, online browsing and other behaviours, has been suggested as a potential risk factor for increased psychiatric symptoms. Two main theories have been put forward to explain this association.

The first, known as the "displacement hypothesis", proposes that digital media engagement may displace other behaviours which potentially promote better mental wellbeing (Puukko et al., 2020; Twenge et al., 2018). Twenge and colleagues (Twenge et al., 2018) suggest that displacement may have both direct and indirect effects if the loss of the displaced behaviour has a negative effect as well as digital

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media engagement itself.

Second, the "social compensation" hypothesis proposes that online engagement may be driven by a pre-existing psychological or psychosocial issues, and that online engagement is one of the symptoms, potentially attempting to compensate for existing issues (Puukko et al., 2020). Its also possible online engagement does not act through either of these processes, but is, instead initiated by exposure to adverse content online, or through other mechanisms not yet identified.

As stated, results surrounding the associations between digital media engagement and mental wellbeing are mixed as seen in recent reviews. Odgers & Jensen (Odgers & Jensen, 2020) synthesised the existing literature reviews published between 2014 and 2019 and found very little consistency within the literature, with studies showing positive, negative and non-significant associations. Of the six reviews included, three focused exclusively on adolescent populations, our population of interest. The largest of these, conducted by Best et al. (Best et al., 2014) found mixed reviews, suggesting benefits of social media, including increased self-esteem and perceived social support, but also adverse effects including increased isolation and depression scores. However, Odgers & Jensen (Odgers & Jensen, 2020) point out the potential over-inclusivity of the review, which included studies utilizing various different methodologies (e.g. reviews, qualitative, quantitative) and measures of technology use. Keles et al. (Keles et al., 2020) and McCrae et al. (McCrae et al., 2017) both reported small but significant associations between social media use and increased mental health symptoms. Importantly, the authors of these reviews noted the over-reliance on cross sectional study designs, leading to an inability to make causal inferences. Finally, a recent review by Dienlin & Johannes (Dienlin & Johannes, 2020) reported that moderate usage may be somewhat protective over low usage and high usage and again, this review pointed out many methodological flaws in the existing literature including issues regarding sample sizes, follow-up time, study design and causality issues. This paper addresses these gaps in the literature by using a large scale, nationally-representative cohort followed-up over a period of 8 years to assess of the associations between use of digital devices (specifically time spent online) at ages 13 and 17 and psychiatric symptoms reported at age 17, while being able to adjust for age 9 predisposition to psychiatric symptoms.

Across studies of psychiatric wellbeing, the prevalence of depression and anxiety tends to be higher among women (Ayuso-Mateos et al., 2001; Mojtabai et al., 2016). This sex difference has been reported internationally, with global burden of disease studies showing depression and anxiety as the 3rd and 8th largest causes of years lived with disabilities in women respectively, compared to the 5th and 13th in men (James et al., 2018). The higher rates of depression and anxiety among women also seem to be apparent in relation to social media usage, with women reporting more time on smartphones, social media, texting, general computer use, and online compared to males, as well as increased negative effects of digital media on mental wellbeing (McNamee et al., 2021; Twenge & Martin, 2020). This study will examine to what extent associations between digital media and psychiatric symptomology differ between the sexes.

This study aims to examine the relationship between use of digital devices and psychiatric symptoms, drawing upon nationally representative, longitudinal data from an Irish child cohort study (the Growing Up in Ireland (GUI) cohort study). Previous research using these data have found that phone ownership at an earlier age is associated with decreased performance in standardised maths and reading test across both boys and girls (Dempsey et al., 2019) and worse behavioural adjustment and academic self-concept among girls both at age 9 (Dempsey et al., 2020). Additionally, using both GUI cohorts, cohort 98 and cohort 08, Bohnert & Gracia (Bohnert & Gracia, 2021), found associations between TV/digital media use, measures of screentime, and media engagement, a binary variable of behavioural engagement, with significant reductions in overall psychiatric symptoms.

This study establishes latent class groups (LCGs) of engagement with digital media at ages 13 and 17, incorporating both time based and behavioural measures, and then examine their relationships with psychiatric symptoms at age 17/18 for males and females. We also aim to examine whether our age 13 digital media engagement groups predict placement in our age 17 digital media engagement groups. We hypothesise that engagement at 13 will predict engagement at 17 and that both high a low engagement at both ages will lead to increased psychiatric symptoms. To sumarise, we aimed to answer the following research questions; 1) Does digital media engagement during adolescence impact later adolescent mental wellbeing and 2) Does early adolescent digital media engagement predict late adolescent engagement.

2. Methods

2.1. Participants

This study uses Cohort98 from the Growing Up in Ireland Study (GUI), a nationally representative, longitudinal cohort (Murray et al., 2010 ; Thornton et al., 2016; Murphy et al., 2018) of young people first sampled age 9 in 2007, and subsequently followed up age 13 in 2011 and age 17 in 2016. Data collection at age 9 was based on a two-stage cluster sample and included 8568 participants. Wave two conducted 4 years later at age 13 retained 88% (N = 7525) members of the initial sample and wave three, at age 17/18, retained 72.5% of the original sample (N = 6216).

The sample is weighted during analysis in order to ensure representativeness and account for attrition of the sample across the waves. For this analysis, we only used the 3 wave combinational weight, suitable for use when the analysis want to examine those who participated in all 3 data collection waves, age 9, 13 and 17/18. The creation of the weighting factor used a standard iterative procedure, based on a minimum information loss algorithm which used pre-determined factors to produce estimates as accurately as possible. Futher details of the population weighting procedure can be found in the GUI "Design, Instrumentation and Procedures for Cohort '98 at 17/18 years of age" (Murphy et al., 2018).

2.2. Exposure variables

Our primary exposure for this analysis will be placement into the individual groups within our two separate LCA models, one for age 13 and another for age 17. The creation of these models required indicator variables including various forms of digital engagement which was measured using child self-reported items regarding time spent online and online behaviours undertaken at age 13, and 17/18. Latent class analysis (LCA, detailed below and in appendix 1, 2 & 3) at each wave identified groups with shared patterns of computer use and time online. It is important to note here, while we attempted to keep our latent class indicator variables as similar as possible, some variables differed between timepoints and therefore estimate different latent class models at each age.

At age 13, our first latent indicator variables is child-self reported time on the computer on weekdays outside of school, grouped into five levels: none; less than an hour; 1–2 h; 2–3 h; 3+ hours. Initially, this variable was collected in 30 min intervals, ranging from 0 min, to 361+ minutes. We shortened this variable to match the format of the age 17 time online question. It is important to note here, at age 13 we only have time based usage for the weekdays, not weekends. In addition at 13, binary variables (engagement yes/no) measured online behaviour, asking the child to respond with yes if they ingage with 'gaming', 'surfing the internet', 'watching movies/listening to music', 'homework', 'school projects' and engaging with "social media".

At age 17, our latent class variable uses two measures of "time online" one specific for weekdays and another for weekends. Both these measures are collected a 5 point categorical variables, with the

following options; none; less than an hour; 1–2 h; 2–3 h; 3+ hours. The question referred to a typical day, and asked based on the assumption it was their primary behaviour at the time. Again, we also had binary measures of behavioural engagement, "yes/no"for age 17 including 'sharing photos and videos', 'messaging', 'school/college work', 'watching videos' and 'listening to music'. These variables specifically asked "When you use the internet, what do you use it for" which the child then answered yes to each of the supplied behaviours that applied to them.

At age 17, a binary variable indicating engagement with social media was also asked, however it was excluded during the creation process as it did not differ meaningfully between classes in most models. As will be stated earlier the inclusion or exclusion of this variable made no impact on our latent classes, possibly because the "behaviours" social media promotes, have been covered with out other behavioural measures such as sharing photos/videos and messaging.

2.3. Outcome variables – psychiatric symptoms

The outcome variable used in this analysis is psychiatric symptoms as measured by the Strengths and Difficulties Questionnaire (Goodman et al., 1998) (SDQ), reported by the parent at 13 and 17. The SDQ is a non-diagnostic, symptom-based tool widely used to assess psychiatric symptomology. It includes five scales, four of which measure adverse psychiatric symptom, emotional, peer problems, hyperactivity and conduct, which can be used individually or fused to form two 'disordered categories': an internalizing (sum of the 'emotional problems' and 'peer problems' subscales), and an externalizing scale (sum of the 'hyperactivity' and 'conduct problem' subscales). As this study examines problematic psychiatric symptoms, the fifth subscale ('prosocial behaviour') was not included in this analysis. For the analysis, the total psychiatric symptom' score was constructed by summing the four individual symptom scales.

2.4. Analysis strategy

The GUI data provides a measure of the dependent variable, psychiatric symptoms, at age 9, 13 and 17/18 which gives us the ability to adjust for baseline psychiatric symptoms at age 9 when estimating the effects of online behaviours on psychiatric symptoms at both age 13 and 17/18. Additionally, examining the impact of digital media engagement at 17, we can adjust for usage at age 13 to establish a baseline.

Currently available studies examining digital media engagement and psychiatric wellbeing have been mixed, but this is possible due to whats been coined the goldilocks effect (Przybylski & Weinstein, 2017). While we will discuss this in detail later, the goldilocks effect suggests moderate digital media engagement is beneficial, which has been somewhat observed in the data with effects being seen with both high and low usage (Dienlin & Johannes, 2020). Therefore, we will be using the moderate usage grouping in our LCA's models as our baselines for the following analysis.

Previous research has shown that poor psychological adjustment and psychiatric symptoms are more prevalent among young people from more socially and economically disadvantaged households (Layte & McCrory, 2018) and moreover, that online behaviours vary by social position (Dempsey et al., 2019). To prevent confounding, we adjust for social and economic position using maternal level of education. In addition, we also fit a binary variable indicating the presence of a diagnosed psychiatric disorder at age 9 to remove the possibility that a previous diagnosis may explain the behaviour.

2.5. Statistical analysis

Information on the creation of our latent classes at age 13 and 17 is provided in detail in appendix 1. Briefly, GSEM and doLCA methods (STATA 16.1 (StataCorp, 2019)) were used to create and verify our LCGs, with the GSEM models being the primary method of classification. A 4 group model suited both sets of data at age 13 and 17/18 based on a number of factors including fit indices (AIC, BIC, adj.BIC, entropy), definability and uniqueness of individual groups (see appendix 3 for a detailed outline using out age 17 LCA) and suitability towards our research question. Multinomial logistic regression was used to test associations between the two LCGs at age 13 and 17. Linear regression models examined the associations between our LCGs at age 13 and 17 and psychiatric symptom scores.

2.6. Missing data

At Age 17 our measures of time online, had an option "difficult to say, some time every day." As this final answer does not meaningfully provide information on time spent online, we decided to exclude this from the analysis, leading to 721 exclusions for the weekday variable and 750 exclusions for the weekend variables. Additionally, a further 8 participants either refused to answer or did not know their time online for weekdays and weekends, so these answers were altered to "missing." As these variables were the greatest contrast among our age 17 LCA groups, we therefore excluded individuals missing either of these variables, leading to a sample size on 5229.

At age 13, missing data led to 115 exclusions from our latent class model. Across all indicator variables, we were able to exclude based on absence of the binary variables in this instance as they had to select Yes/No when answering.

Of those included in the latent class analysis, there were an additional 43 individuals excluded from our analysis as they were missing SDQ information at age 17 and 31 at age 13.

2.7. Confounders & adjustments

As stated, psychological adjustment has been shown to be impacted by socioeconomic status (SES), with poorer outcomes coming from those in socially and economically disadvantaged households (Layte & McCrory, 2018), therefore we adjust for maternal highest achieved education, split into lower secondary, higher secondary, post secondary and third level, as a proxy measure of SES.

As our exposure is behavioural, it is possible to argue that our outcome, psychiatric symptoms, may drive the behaviour, rather than the behaviours being a risk factor for the symptoms. We took two steps to adjust for this possibility, firstly, we adjusted for psychiatric symptoms at age 9, prior to both our exposures to adjust for potential predispositions to certain symptoms, secondly we adjusted for a prediagnosed psychiatric disorder also at age 9, to account for the possibility that it's a disorder driving the behaviour.

Finally, when examining age 17 digital usage, we adjust for age 13 usage as a baseline, in an attempt to examine the impact of digital usage across time, and whether the associations persistfrom adolescence to young adulthood.

3. Results

3.1. Descriptive statistics & latent class profiles

3.1.1. Latent class groups at age 17

At age 17, as outlined, we used time spent online during the weekend and weekday, as well as binary measures of various online behaviours. After excluding missing data, our class models included 5229 individuals of the 6216 participants at age 17/8. Profiles of the groups for the preferred 4 class solution are shown in Table 1 and Fig. 1. The first group is labelled the "High Time Spent and Behavioural Engagement (HT-HE-17)" group because it reported the highest time online among the groups as well as the highest proportion reporting all of the different behaviours online.

The second group, the "moderate time spent and high behavioural

Table 1
Group distribution, gender distribution, means for grouping variables.

Class	N	Female (%)	Time Online Weekday (Categorical mean)	Time online Weekend (Categorical mean)	Messages Online	Shared Photos or Videos	School or College Work	Watches Movies	Listens to Music
Low Engagement (LT-ME-17)	853	358 (41.97)	2.38	2.67	0.81	0.72	0.67	0.88	0.87
Low Time, Behavioural Engagement (LT-LE-17)	175	51 (29.14)	2.29	2.35	0.059	0.16	0.31	0.39	0.23
Moderate Engagement (MT-HE-17)	2253	1095 (48.6)	3.24	4.01	0.90	0.88	0.84	0.96	0.94
High Engagement (HT-HE-17)	1948	1103 (56.62)	4.63	4.91	0.91	0.89	0.78	0.96	0.95

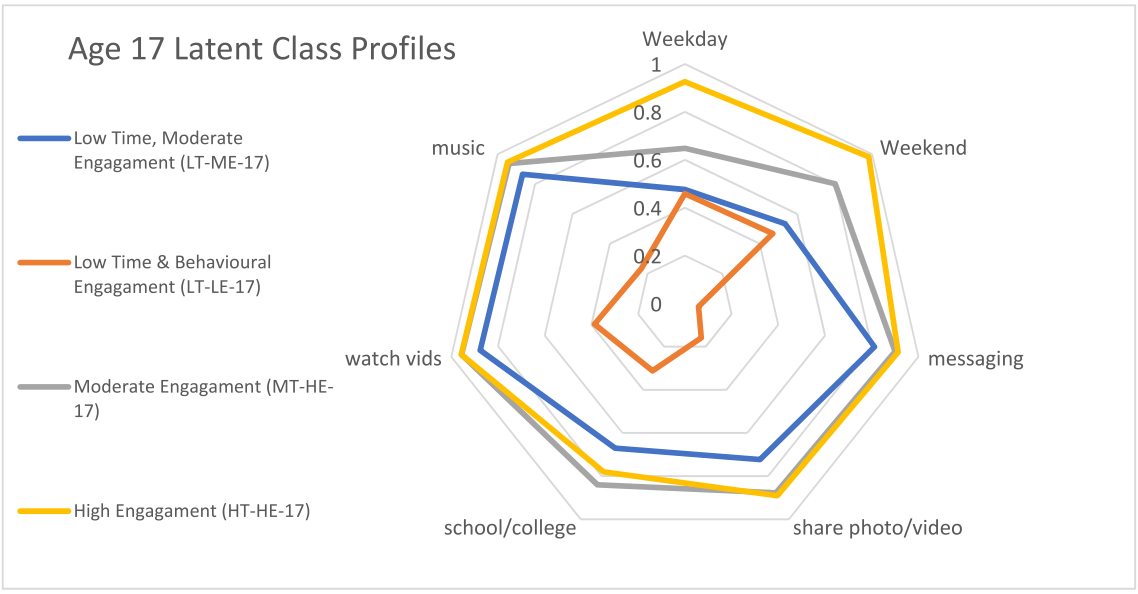

Fig. 1. Age 17 Latent class profiles of digital usage at age 17.*Weekend and Weekday Time online variable take the form of 1–5, as seen in the group means, however group means were divided by 5 here to make them consistent with the behavioural variables.

engagement (MT-HE-17)", is characterised by reduced time online compared to our "high" group, but a similar pattern of behavioural engagement (messaging, sharing pictures, school work etc) to the HT-HE-17 group.

Our last two groups are characterised by lower engagement both in terms of time spent online and types of online activities. The "low time, moderate behavioural engagement" group (LT-ME-17) and the "low time, low behavioural engagement group (LT-LE-17), both spend approximately 1–2 h online on weekdays and weekends but the LT-LE-17 group have lower engagement with all of the different types of online behaviours. Table 1 shows the group means for all indicator variables for each of our latent classes, and Fig. 1 shows the different profiles plotted on a radar plot, with the Weekday and Weekend time online variables divided by 5 to keep consistency with the binary engagement variables.

Our MT-HE-17 group was the largest with 2253 members, followed by our HT-HE-17 group inclusive of 1948 members. Finally our LT-ME-17 contained 853 members and the LT-LE-17 group contained just 175 members.

The breakdown of the latent classes by sex can be seen in Table 1, with the profiles in Fig. 2. It is worth pointing out here the discrepancy in the LT-LE-17 group, with 70.86% of the group being males.

Our Latent profiles by sex show some differentiation, the main difference being that females show wider usage in the LT-LE-17 grouping, with increased reported engagement with all behaviours.

3.1.2. *Latent class groups at age 13*

A four class solution was also found to fit the data best at age 13 (see Fig. 3). At 13, the "high time & engagement" (HT-HE-13) group had the highest reported online time among the groups (between 1 & 2 h daily) and high mean scores for each individual online behaviour. This is also the only group to show high levels of widespread behavioural usage.

The second group is the "moderate time, excluding education" (MT-EE-13) group, who engage in entertainment only behaviours, (surfing the web, watching movies & listening to music, and gaming) but almost no engagement with homework and school projects. This group is denoted by lower reported time usage compared to our high group (<1 h daily on average).

Our third group is labelled the "moderate time & engagement group" (MT-ME-13). This group are characterised by low levels of surfing and gaming but higher use of the internet for homework and school projects. Time-wise, this group reports approximately 1 h engagement per day, similar to our ME-EE-13 group.

The final group is our low time, moderate engagement group (LT-ME-13), primarily named due to their reporting of very low time spent engaging and socialising online. Their group mean indicates no engagement online time-wise, however its more appropriate to stay they spend less than an hour online.

Unlike our age 17 variables, the time differentials between groups is difficult to determine, however, we are able to test this with a more varied time variable at this age. As we had stated we shortened our time variable at age 13 to remain consistent with our age 17 variable. We

Fig. 2. Age 17 Latent class profiles by sex.

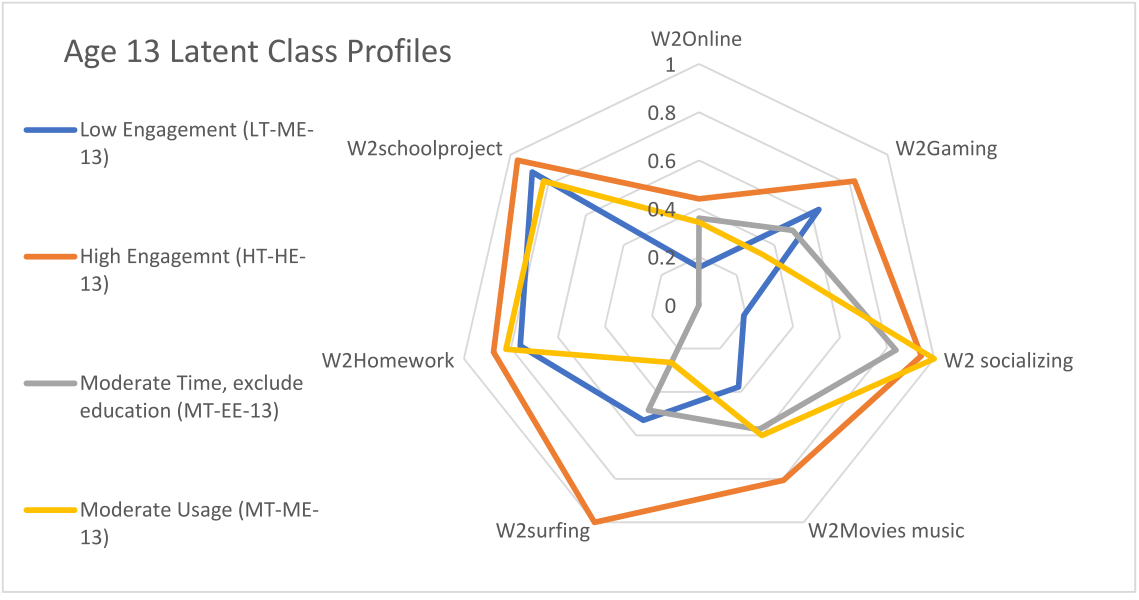

Fig. 3. Age 13 Latent class profiles of digital usage.

found that our low group spent between 1 and 30 min online per day, both moderate groups reported spending 61–90 min online per day, and our high engagement group reported 91–120 min online per day.

Sex differences at age 13 are less distinctive than they were at age 17. Whereas at age 17 we saw differences in our LT-LE-17 group, at age 13 we see very similar groupings with marginal increases in the time spent online for females in each group except the LT-ME-13 group (see Fig. 4).

3.2. Associations between our latent class groups at age 13 and 17

Using both moderate usage groups as our baseline (MT-ME-13 & MT-HE-17), multinomial logistic regressions were used to examine the association between latent class groups at age 13 and 17. Placement in HT-HE-13 group significantly increases the risk of being placed in the HT-HE-17 group (RRR = 1.21, 95% CI = 1.04–1.41), whereas placement in LT-ME-13 significantly reduces the risk of being placed in HT-HE-17 (RRR = 0.80, 95% CI = 0.66–0.98). Placement in LT-ME-13 also led to significantly increased risk of being placed in LT-ME-17 (RRR = 1.43,

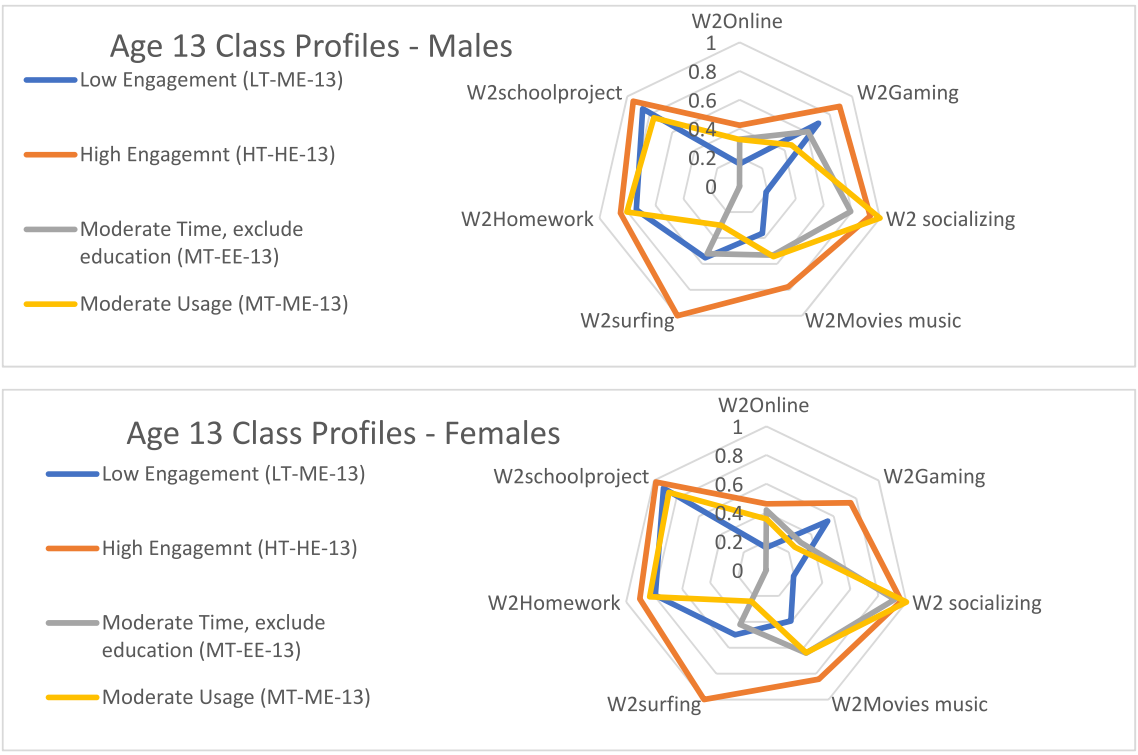

Fig. 4. Age 13 Latent class profiles by Sex.

95% CI = 1.14–1.80) and LT-LE-17 (RRR = 2.49, 95% CI = 1.63–3.79). Interestingly, the final association observed was between our two limited behaviour groups, where placement in ME-EE-13 led to a significantly increased risk of being place in LT-LE-17 (RRR = 3.06, 95% Ci = 2.09–4.49).

3.3. Descriptive analysis

To assess group profiles for individual psychiatric symptoms, we used SDQ scales converted to z scores for the consistency among groups and to allow for graphing. Fig. 5 shows the group means for our psychiatric symptom scales and composite measures.

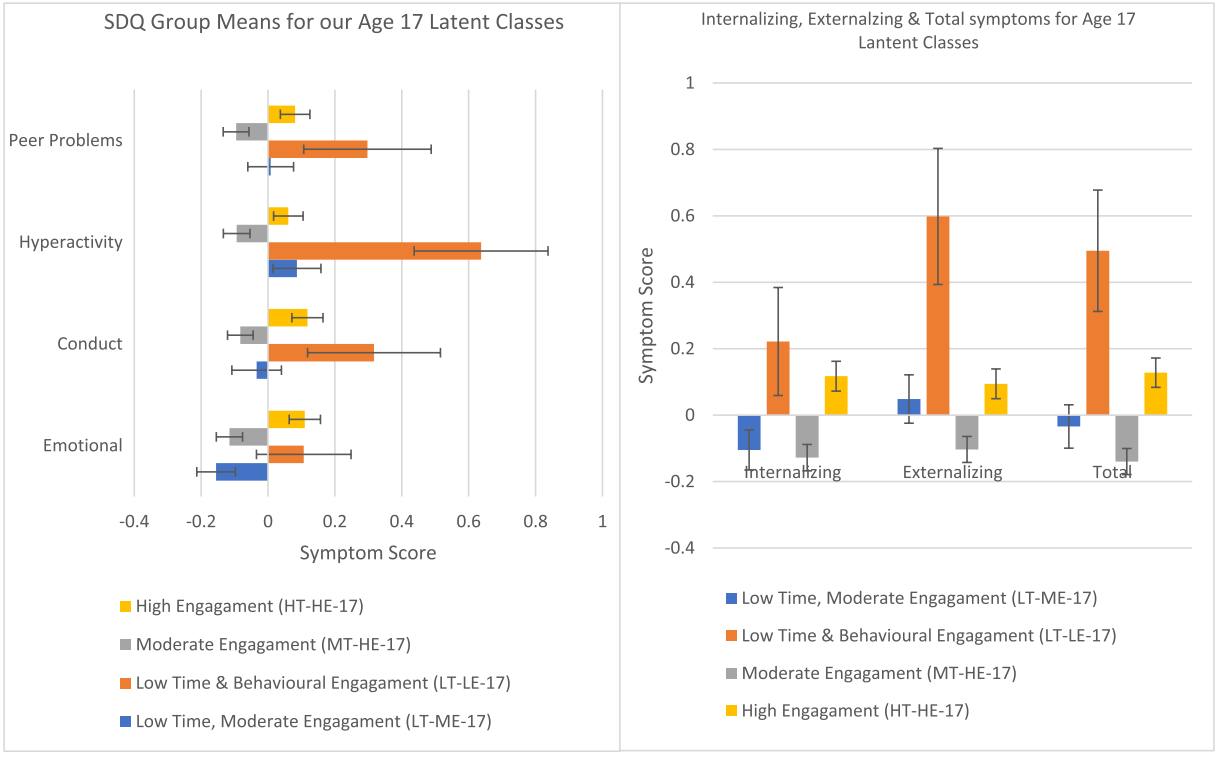

Fig. 5. Group means for the individual and composite psychiatric symptoms at age 17 across the latent class at age 17. Higher scores equated to greater symptoms.

Examining psychiatric symptom profiles by sex, we see that males in LT-LE-17 group display high conduct and hyperactivity symptoms, with females in that group showing negative group means on these scales. Further differences include the high emotional symptom scores reported by females in the HT-HE-17 group, whereas males in the same group show negative effects, indicating that females will drive any associations seen in the overall population (Fig. 5).

3.3.1. Multivariate analysis

Linear regressions were run to assess associations between our latent class groups at age 13 and 17 and psychiatric symptoms at age 17. In both cases, as stated previously, a moderate usage grouping was used as the baseline model, in the case of age 13, the moderate, wide usage group was chosen as the baseline.

Table 2 shows a consistent associations between the "high usage" groups, HT-HE-13 & HT-HE-17, the "limited behaviour groups", ME-EE-13 & LT-LE-17, and psychiatric symptoms age 17.

Next we examined associations between age 13 digital media engagement and age 17 psychiatric symptoms, while adjusting for age 9 baseline psychiatric symptoms, maternal highest education received, and previous diagnosis of a psychiatric disorder (at age 9), while stratifying by sex.

Table 3 shows that, for males, there is a consistent pattern of negative effects for placement in the MT-EE-13 group relative to placement in the MT-ME-13 group. Placement in the former is associated with an increase in each psychiatric symptom except emotional symptoms. For females, we see that placement in HT-HE-13 is associated with increased internalizing symptoms at age 17, while being part of MT-EE-13 is associated with widespread increases in all symptoms except emotional symptoms at 17, similar to males.

By adjusting for baseline psychiatric symptoms measured at age 9, as well as adjusting for a psychiatric diagnosis at age 9, we can account for predisposition to internalizing and externalizing symptoms. We also incorporate both latent classes into one model, using age 17 as the main exposure, while adjusting for age 13 latent class groups as a baseline. Additionally, we adjusted for family socioeconomic position using maternal highest level of education. Finally, with the sex differences being so prevalent in the symptom profiles (see Fig. 6), we stratified the adjusted models by sex.

Table 4 shows that female placement in LT-LE-17 group does not show any associations with psychiatric symptoms, although this is likely to reflect the low numbers of women in this group (N = 51). For males, this group shows consistent, highly significant ($p < 0.001$) associations between LT-LE-17 and all psychiatric symptoms.

The HT-HE-17 group remains highly consistent for increases in all psychiatric symptoms in females, with the highest associations for psychiatric symptoms being observed for emotional symptoms. In males, placement in HT-HE-17 shows consistent associations for increases in internalizing symptoms, emotional and peer problems and the combined internalizing scale, but regarding externalizing symptoms, while the association remains high for conduct symptoms, no associations are present for the hyperactivity scale.

Finally, females in the LE-ME-17 group do have significant associations with increased peer problems.

4. Discussion

After adjustment for maternal education, baseline symptoms at age 9 and pre-diagnosed psychiatric disorders, placement in HT-HE-13 at age 13 was associated with increased internalizing symptoms among female participants, while both sexes showed increases of all symptom, except emotional, if placed in MT-EE-13 group. At 17, after adjustment for maternal education, baseline symptoms at age 9, digital engagement at age 13 and pre-diagnosed psychiatric disorders, we found that allocation to HT-HE-17 was associated with widespread decreases in mental wellbeing among females, across all psychiatric symptoms. Among males, allocation to HT-HE-17 was also associated with increased internalizing symptoms, while allocation to the LT-LE-17 group was associated with widespread increases in psychiatric symptoms. Our results are consistent with some existing studies reporting curvilinear relationships between digital media engagement and mental wellbeing (Przybylski & Weinstein, 2017), however, the existence of a curvilinear relationship may explain why we see discrepancies with other studies examining purely linear models. Our study highlights possible potential positive effects of moderate, non-passive usage (Best et al., 2014; McNamee et al., 2021; Przybylski & Weinstein, 2017), with our MT-ME-13 and our MT-ME-17 groups showing the lowest symptoms scores. Additionally, large scale reviews of the area (Dienlin & Johannes, 2020; Keles et al., 2020; McCrae et al., 2017) also report the benefits of moderate internet usage for psychiatric outcomes compared to both low and high use, again in line with our results, where we see negative effects of both high and low usage. These results also support what is known as the 'Goldilocks' theory (Przybylski & Weinstein, 2017), the idea that moderate usage is beneficial. If this beneficial effect of moderate usage is true, it may explain as to why some studies, only examining time based exposure, specifically those using "no engagement" or

Table 2
Unadjusted regression examining the association between latent class profiles at age 13 and 17 and psychiatric symptoms at age 17.

	SDQ measured Psychiatric Symptoms at age 17(Coef, 95% CI)						
	Emotional	**Conduct**	**Hyperactivity**	**Peer Problems**	**Internalizing**	**Externalizing**	**Total**
Latent Class Group Age 13							
Low Engagement (LT-ME-13)	−0.33 (−0.50 to −0.17)***	−0.16 (−0.27 to −0.05)**	0.01 (−0.16–0.18)	0.06 (−0.05–0.18)	−0.27 (−0.51 to −0.03)*	−0.15 (−0.39–0.09)	−0.42 (−0.82 to −0.02)*
Moderate, exclude education (MT-EE-13)	−0.02 (−0.17–0.13)	0.26 (0.16–0.35)***	0.23 (0.09–0.38)***	0.26 (0.16–0.37)***	0.24 (0.03–0.46)*	0.95 (0.73–1.17)***	1.20 (0.84–1.56)***
Moderate, all usage (MT-ME-13; BASELINE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-13)	0.15 (0.02–0.29)*	0.08 (−0.003–0.17)	0.70 (0.54–0.86)***	0.28 (0.19–0.38)***	0.43 (0.24–0.63)***	0.32 (0.12–0.51)***	0.75 (0.43–1.07)***
Latent Class Group Age 17							
Low Engagement (LT-ME-17)	−0.08 (−0.25–0.09)	0.06 (−0.04–0.16)	0.39 (0.22–0.56)***	0.15 (0.037–0.28)*	0.07 (−0.16–0.29)	0.45 (0.21–0.69)***	0.52 (0.14–0.90)*
Low Time & Behavioural Engagement (LT-LE-17)	0.46 (0.18–0.75)**	0.50 (0.32 - .69)***	1.58 (1.27–1.89)***	0.58 (0.37–0.78)***	1.04 (0.63–1.45)***	2.09 (1.66–2.51)***	3.13 (2.45–3.81)***
Moderate Usage (MT-ME-17; Baseline)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-17)	0.47 (0.35–0.60)***	0.25 (0.17–0.33)***	0.33 (0.20–0.47)***	0.26 (0.17–0.35)***	0.73 (0.55–0.91)***	0.59 (0.40–0.77)***	1.32 (1.02–1.61)***

*P < 0.05; **P < 0.005; ***P < 0.001.

Table 3
Adjusted Effects of LCA Group Age 13 on age 17 psyciatric symptom symptoms, split by sex, and adjusting for baseline symptoms at age 9, prediagnised psychiatric disorders and maternal SES.

	SDQ measured Psychiatric Symptoms (Coef, 95% CI)						
	Emotional	**Conduct**	**Hyperactivity**	**Peer Problems**	**Internalizing**	**Externalizing**	**Total**
Latent Class Group Age 13 MALES							
Low Engagement (LT-ME-13)	0.02 (−0.16–0.20)	−0.22 (−0.37 to −0.07)**	−0.07 (−0.32–0.18)	0.14 (−0.02–0.30)	0.19 (−0.08–0.46)	−0.11 (−0.42–0.18)	−0.14 (−0.64–0.36)
Moderate, exclude education (MT-EE-13)	0.11 (−0.05–0.27)	0.19 (0.06–0.33)**	0.40 (0.18–0.63)***	0.16 (0.02 (0.31)*	0.26 (0.02–0.51)*	0.36 (0.09–0.64)**	0.87 (0.42–1.31)***
Moderate, all usage (MT-ME-13; BASELINE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-13)	0.02 (−0.13–0.18)	0.07 (−0.05–0.20)	0.05 (−0.17–0.26)	0.19 (0.05–0.32)*	0.17 (−0.06–0.40)	0.12 (−0.14–0.38)	0.33 (−0.09–0.76)
Latent Class Group Age 13 FEMALES							
Low Engagement (LT-ME-13)	−0.44 (−0.69 to −0.20)***	−0.10 (−0.25–0.05)	−0.13 (−0.36–0.10)	−0.07 (−0.23–0.09)	−0.53 (−0.86 to −0.20)**	−0.17 (−0.46–0.13)	−0.75 (−1.31 to −0.19)*
Moderate, exclude education (MT-EE-13)	0.10 (−0.13–0.33)	0.27 (0.13–0.41)***	0.58 (0.36–0.80)***	0.24 (0.09–0.39)**	0.30 (0.01–0.61)	0.55 (0.27–0.82)***	1.19 (0.66–1.72)***
Moderate, all usage (MT-ME-13; BASELINE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-13)	0.32 (0.13–0.50)***	0.0002 (−0.11–0.11)	0.08 (−0.09–0.26)	0.26 (0.14–0.39)***	0.51 (0.25–0.76)***	0.12 (−0.34–0.10)	0.67 (0.23–1.10)**

*P < 0.05; **P < 0.005; ***P < 0.001.

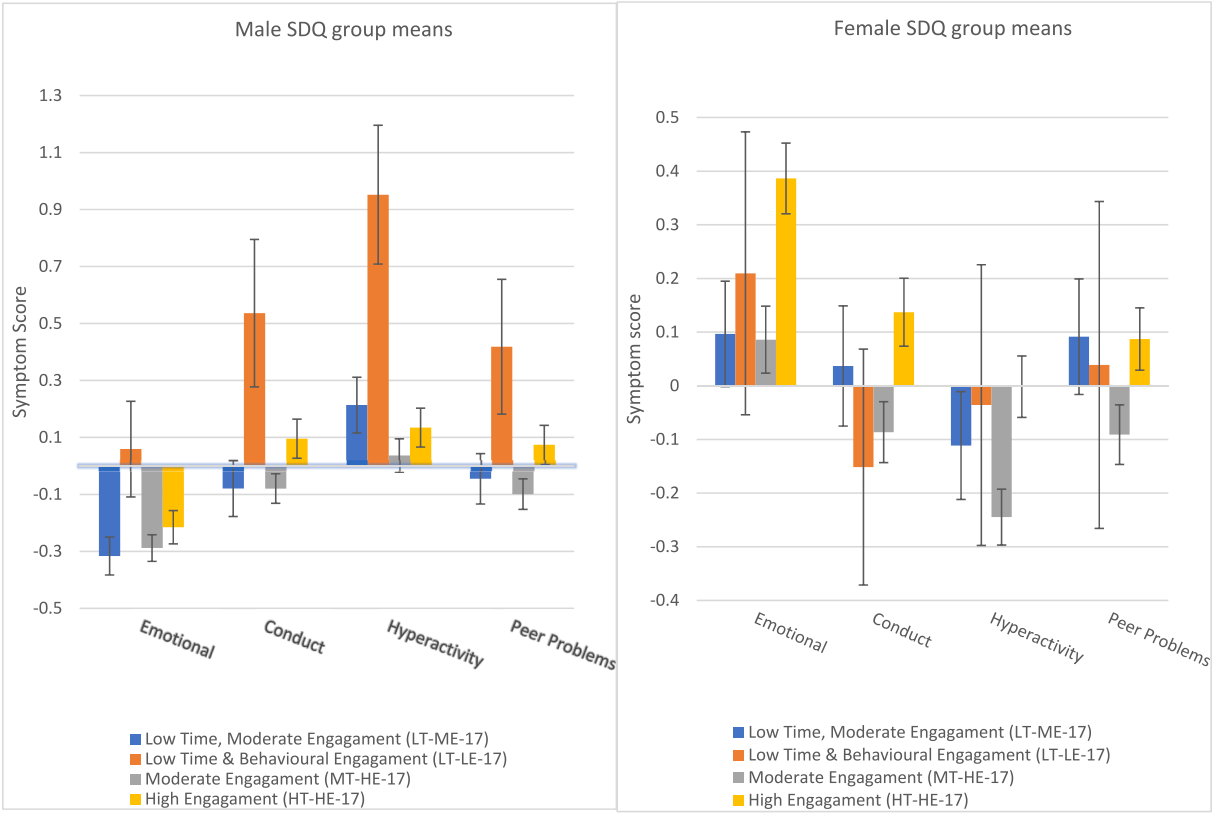

Fig. 6. Group means for SDQ symptoms at age 17, across the 4 Latent groups at 17, further divided by sex. Higher scores equated to greater symptoms.

"low time based engagement" as the referent group, or running linear modelling, would find null results. Our results also suggest that the types of activities engaged with online are also important. The group lacking engagement with educational behaviours at 13, MT-EE-13, or those adopting passive engagement at 17, LT-LE-17, displayed increased psychiatric symptoms, especially in males. The importance of the type of online behaviours has been suggested before as an area to consider when conducting research in this area (Przybylski & Weinstein, 2017), with Twenge & Martin (Twenge & Martin, 2020) showing clear differences in the impact on mental wellbeing of different online behaviours. Additionally, the potential negative effects of passive engagement has been shown previously, with Verduyn and colleagues (Verduyn et al., 2015), with passive facebook use leading to decreased scored in affective wellbeing. Our results are in line with these finding, especially those

Table 4
Adjusted Effects of LCA Group Age 17 on age 17 psychiatric symptoms, split by sex, and adjusting for baseline symptoms at age 9, prediagnised psychiatric disorders, age 13 digital media engagement and maternal SES.

	SDQ measured Psychiatric Symptoms (Coef, 95% CI)						
	Emotional	**Conduct**	**Hyperactivity**	**Peer Problems**	**Internalizing**	**Externalizing**	**Total**
Latent Class Group Age 17 MALES							
Low Engagement (LT-ME-17)	−0.12 (−0.29–0.04)	0.04 (−0.08–0.17)	0.21 (−0.003–0.43)	0.06 (−0.09–0.20)	−0.07 (−0.33–0.18)	0.25 (−0.05–0.54)	0.15 (−0.28–0.58)
Low Time & Behavioural Engagement (LT-LE-17)	0.62 (0.34–0.91)***	0.51 (0.29–0.72)***	1.21 (0.84–1.57)***	0.53 (0.28–0.78)***	1.15 (0.72–1.58)***	1.61 (1.12–2.10)***	2.75 (2.02–3.48)***
Moderate Usage (MT-ME-17; Baseline)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-17)	0.14 (0.00–0.28)*	0.19 (0.09–0.30)***	0.09 (−0.09–0.27)	0.25 (0.12–0.37)***	0.40 (0.19–0.61)***	0.26 (0.02–0.50)	0.66 (0.30–1.02)***
Latent Class Group Age 17 FEMALES							
Low Engagement (LT-ME-17)	0.03 (−0.21–0.28)	0.07 (−0.07–0.22)	0.18 (−0.04–0.40)	0.26 (0.09–0.42)**	0.29 (−0.06–0.63)	0.23 (−0.07–0.54)	0.48 (−0.06–1.02)
Low Time & Behavioural Engagement (LT-LE-17)	0.10 (−0.40–0.60)	−0.16 (−0.45–0.13)	0.12 (−0.32–0.55)	−0.04 (−0.37–0.29)	−0.01 (−0.67–0.70)	−0.06 (−0.68–0.56)	−0.09 (−1.16–0.98)
Moderate Usage (MT-ME-17; Baseline)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
High Engagement (HT-HE-17)	0.50 (0.32–0.67)***	0.16 (0.06–0.26)**	0.28 (0.13–0.44)***	0.18 (0.06–0.29)**	0.66 (0.42–0.90)***	0.42 (0.20–0.63)***	1.02 (0.64–1.40)***

*P < 0.05; **P < 0.005; ***P < 0.001.

placed within the LT-LE-17 group. Our results show considerable sex differences in the impact of digital media use, whereas females seem more susceptible to the negative impact of high usage, and males the negative impact of low, or passive usage. This is not the first study to report sex specific effects of digital media usage, with studies reporting worse behavioural adjustment and academic self-concept in females (Dempsey et al., 2020). Mcdool and colleagues (McDool et al., 2020) found that internet usage was associated with decreased mental well-being in adolescents (age 13+) across both genders, with the largest impact for body image and how one feels about appearance. The effects were worse for females compared to males. Additionally, studies specifically addressing mental health found that while significant negative effects are found for high usage (4+ hours per day) across both sexes, girls are more negatively impacted than boys on overall mental health scores (McNamee et al., 2021), this can also be observed within our results, whereby we see females placed in the HT-HE-13 and HT-HE-17 groups showing higher regression coefficients compare to males placed in these groups. This is particularly realivent at age 17, where both groups show significant results. However, males are more impacted in the domains of hyperactivity and conduct. Finally, Twenge & Martin (Twenge & Martin, 2020) also reported greater impacts of digital media on mental wellbeing for females over males. However, they also report gender usage differences, with females engaging more with the internet and general computer usage, especially in social behaviours such as, messaging and social media. Overall, our analysis attempted to tie both the time-based, and behavioural aspects of digital media engagement together, to examine them as a single entity. We believe this is the first study to undertake this task, and our results suggest that while high digital media engagement may have negative effect on metal wellbeing, possibly linked to the time based exposure potentially displacing other pro-mental wellbeing activities, the negative effects of those reporting lower digital media engagement usage, may stem from the behaviours, specifically passive behaviour at age 17 and a lack of educational behaviour at age 13. As shown above, our results are consistent with previous studies, regarding sex differences, time based exposure and behavioural exposures. In the next section we discuss potential mechanisms by through which these effects may occur. By understanding potential causal pathways and their policy implications, it will be possible to develop public health strategies for preventation or early identification of those young people who are at risk.

4.1. Potential mechanics & current theories

There are a number of prevailing theories that attempt to explain why we are observing increased psychiatric symptoms among high users of digital media. Displacement theory suggests that increased social media engagement crowds out other forms of behaviour which promote positive mental wellbeing (Puukko et al., 2020; Twenge et al., 2018). There is long-standing evidence for this hypothesis, with reported increases in digital usage associated with declines in communication with family members and reduction in the size of social circles (Kraut et al., 1998), as well as research suggesting it as being one factor on the causal pathway for the decline in “adult activities” among adolescents such as sex and drinking (Twenge & Park, 2019). However, our results are mixed, suggesting that this may not be the sole mechanism at play. While displacement theory may be supported among our “high usage” groups, the effects of our low engagement group in males suggests that this may not be the only mechanism by which digital media impacts mental wellbeing. The digital goldilocks hypothesis suggests that moderate digital media usage is not naturally harmful, and in fact may be somewhat advantageous in the connected world (McNamee et al., 2021; Przybylski & Weinstein, 2017), with both ‘under’ and ‘over’ usage being harmful for mental wellbeing. This theory is supported by our results, with placement to our moderate usage groups, MT-ME-13 and MT-HE-17, having a positive impact, showing reduced psychiatric symptoms compared to placement in high engagement groups, HT-HE-17 & HT-HE-13, or our limited behavioural groups, LT-LE-17 & ME-EE-13. This hypothesis suggests that moderate usage of digital media, may not displace activities which promote positive well-being but instead substitute these behaviours for alternative, similarly effective or potentially more positive behaviours. For example, online gaming could be viewed as providing an intrinsically social environment and with apps such as Geocaching promoting a healthy lifestyle (Przybylski & Weinstein, 2017; O’Hara, 2008). Our results somewhat suggest this in our longitudinal analysis, where our “moderate usage, excluding education”, MT-EE-13 group, which ignore educational usage behaviours online, have increased psychiatric symptoms over our moderate baseline groups, highlighting the importance of the specific behaviours engaged with, which in this case are educational behaviours. An alternate theory is that the direction of causality is actually the reverse, i.e. an individual with pre-existing mental health difficulties may use social media to compensate for psychosocial difficulties. This theory has been labelled ‘social compensation’ (Puukko et al., 2020). In an attempt to exclude this possibility, our study controls for pre-existing psychiatric

symptoms at age 9. We find that significant effects of internet use persisted after adjustment for psychiatric conditions. However, at age 9 it is unlikely that our adjustment captured the totality of internalizing conditions such as depression, which have been shown to have increased prevalence between the ages of 12 and 20 (Mojtabai et al., 2016), thus we cannot rule out that social compensation may occur. It has also been suggested in existing literature that digital usage may not have a causal role in impacting mental wellbeing. Coyne et al. (2020) found no association between time spent on social media and mental wellbeing in an 8 year longitudinal study, however, these results were subject only to time on social media, not general time online or other online behaviours, meaning generalization of null effects would be inappropriate.

4.2. Suggestions for future research

While these theories all attempt to quantify the relationships between digital media usage and mental wellbeing and the mechanisms underpinning these associations, they do not allow for assumptions relating to causality and which other factors which may lie on the causal pathway. In this paper, we have established our latent class groupings, shown consistency with the existing literature and now plan to use them to examine potential causal models in future papers. Preparing for this, here we suggest a potential mechanism by which digital media use may impact mental wellbeing which we coin "sustained social involvement and evaluation". Social involvement and evaluation refers to a combination of factors which may be linked to both online technology use and mental wellbeing. The hypothesis is that digital media does not allow for "social involvement and evaluation shutoff". It could be argued that previous generations were able to separate themselves from social involvement and peer-self comparisons for prolonged periods and thus mitigate the internalization of social comparisons. However, social media allows for constant connection and the curated "digital life" of peers which prevents the current generation of young people from separating themselves from their social context. This may exacerbate potential issues such as low self-esteem, peer isolation or alienation, and negative self-peer comparisons, hence making digital media engagement more of a moderating variable, amplifying the effects of pre-existing vulnerabilities. While we cannot test this hypothesis here, there is tangental evidence supporting this hypothesis. Firstly, adolescence is a period of drastic change cognitively, emotionally and socially (Rosenblum et al., 2003), with studies showing that mental-wellbeing increases as peer attachment increases (Balluerka et al., 2016) suggesting a proportion of their mental wellbeing is drawn from their social circles. A review of 43 studies examining the impacts of online technology use (Puukko et al., 2020) highlighted social isolation and depression as observed negative effects of online technology. Studies have also shown that high online engagement is associated with reduction in the size of social circles (Kraut et al., 1998) and negative impacts on peer relationships (Lloyd et al., 2007). Studies have also shown associations of digital media with factors strongly related to psychosocial adjustment including self-esteem, self-image and body concept and life satisfaction. It is the negative impact of these factors on mental wellbeing that may be exacerbated by social media usage. As stated earlier, Mcdool and colleagues (McDool et al., 2020) showed the negative impact of digital media on one's self-body image during adolescence. Adolescence has been shown to be one of the periods in life associated with the lowest reported self-esteem (Orth et al., 2015). In addition, studies have shown self-esteem and loneliness mediate the impact of social media use on mental wellbeing (Apaolaza et al., 2013). However, it is worth noting that digital media may also be somewhat beneficial to mental wellbeing, with positive associations between online technology use and self-esteem also being reported (Best et al., 2014). Life satisfaction has also been shown to be at its lowest point during adolescence (Gomez et al., 2013). Support for this "social evaluation" model can be found in the fact that peer attachment has been shown to be positively related to life satisfaction, especially for females (Ma & Huebner, 2008), and high life satisfaction during adolescence is associated with higher levels of psychosocial function and lower levels of emotional problems (Suldo & Huebner, 2006). Future research centred on "social evaluation" should place more emphasis on peer connectedness and other associated online social behaviours to more fully investigate this hypothesis. We aim, in future studies, to use our latent classes established here to examine potentially causal models, including factors surrounding and arising from adolescent peer relationships like those discussed above.

4.3. Strengths & limitations

One of the important strengths of this study lies in the use of the GUI cohort, it's sample size, representativeness, and longitudinal nature. Reviews in this subject area have consistently called for large scale samples to be used (Dienlin & Johannes, 2020). With the GUI we have used a large sample, which is nationally representative, hopefully filling this literature gap.

Reviews have also called out for longitudinal approaches to this research area (Dienlin & Johannes, 2020; McCrae et al., 2017; Odgers & Jensen, 2020). As pointed out previously, the majority of research in this area is cross sectional, making it difficult to make causal assumptions related to the observed associations. Being able to examine and subsequently adjust for age 13 digital engagement allows for a longitudinal analysis whilst also enabling us to examine changes in digital engagement across time and its impact on mental wellbeing.

A further strength of this paper lies in the use of both time and behavioural aspects of online usage. As pointed out by Przybylski & Weinstien (Przybylski & Weinstein, 2017), the type of behavioural engagement online matters. This study has attempted to encapsulate both behavioural and time based exposures to attempt to understand their effects, with some results even being centred around behavioural rather that time aspects of online usage. Building on this, while we are limited to what we have included in our LCA models, future studies need to give more attention to the behavioural aspects of online usage rather than just the time aspects.

The primary limitation of this study is the lack of consistent measurement of internet usage across time. As pointed out in the methods, age 13 internet usage was limited to only weekday usage, whereas we had both weekday and weekend usage at age 17. While we attempted to make our latent class groups between age 13 and 17/18 as similar as possible, the lack of weekend information means our two LCA models were not identical. Additionally, binary engagement variables led to low variation in some variables, hences the exclusion of the "social media" variable at 17. Specific behavioural time-based measures would be more informative.

Secondly, we also are limited in our ability to determine time-varying confounders and other social confounding, however this is a frequent limitation across the social sciences. Additional collection waves, with more frequent follow-up times may have accounted for this confounding.

Additionally, while this paper focused on exploring the association between our digital usage latent classes and age 17 psychiatric symptoms we cannot make claims of causality. Therefore, we aim to build upon this study, further building our models by examining potential mediators or moderators of these effects. While we cannot claim causality, we aim to build models to see how digital usage interacts with other "social factors" such as peer relationships and self-esteem. Resonating with what has been said previously, future studies in this area should aim to establish causality, using widely representative longitudinal data with consistent behavioural and time based measures of online usage.

Finally, a 2021 review and meta-analysis conducted by Parry et al. (Parry et al., 2021), reported low convergence between self-reported time-beased measures, and logged usage digital media across the existing literature, with particularly low convergence for problematic usage. While our use of self-report for engagement with digital media is a

limitation, we did attempt to overcome the limitations of self-reports by creating latent class models using multiple forms of online engagement. Conversely, it is also worth pointing out that our results, particularly for the high usage groups (HT-HE-13 & HT-HE-17), may under-represent the actual effect sizes of use on psychiric symptoms. It is possible that if logged measures of usage were used, our LCA models may further differentiate the high usage groups, or more accurately measure the impact of digital engagement on psychiatric wellbeing. In addition to this, we removed a group from our analysis who were unable to approximately estimate their daily digital media engagement (N = 913), introducing a potential introduction of selection bias. For example, its possible that these participants had high engagement, additionally underestimating potential high engagement impacts on mental wellbeing.

5. Conclusions

Both high and low digital usage are associated with increased psychiatric symptoms scores compared to moderate usage. We are able to show that this is the case both cross-sectionally at age 17, and longitudinally, with symptoms measured 4 years after digital usage. At 17, placement in the "high usage", HT-HE-17 group led to widespread symptom increases for females but focused around internalizing symptoms for males. Males allocated to the "low time, low engagement" group at 17, LT-LE-17, also showed widespread increases in reported symptoms. At 13, the "high usage", HT-HE-13, effects we observed for females, were specific to increased internalizing symptoms, whereas both sexes showed "limited behaviour", MT-EE-13, effects, not engaging with online learning educational behaviour, led to increases in all psychiatric symptoms except emotional symptoms. Our results suggest that the impacts of "digital usage" may be gender specific and may also be dependant on the exact dimensions of said usage. Future studies should place greater emphasis on the type of internet activity engaged with rather than just time based measurement, as it may be the quality of these behaviours which drive the observed associations.

Credit author statement

Ross Brannigan PhD – Primary author, was involved in all aspects of the study including idea formulation and preparation. Ross also authored the manuscript and carried out the analysis and model creation. Carlos J. Gil-Hernández PhD – Aided in the formulation of the research questions and subsequent data cleaning and preparation. Olivia McEvoy MSc – Aiding in ongoing, weekly, discussions surrounding the paper, the wider literature and suggestions on how to fill the literature gaps. Was able to provide additional information into the displacement theory and its implications. Frances Cronin PhD – Aiding in ongoing, weekly, discussions surrounding the paper, the wider literature and suggestions on how to fill the literature gaps. Made revisions to the manuscript pre submission and pre revision. Debbi Stanistreet PhD – Obtained funding and oversaw the creation of the paper, guiding the methodology bringing and statistical analysis. Was also able to bring a unique viewpoint to the study surrounding public health, allowing us to suggest future studies and informing us of additional appropriate confounding variables. Richard Layte DPhil – Obtained funding, and guided the development of this study from infancy, informed the statistical analysis as well as the discussion surrounding the potential mechanisms, as well as the importance of the study.

Data availability

THE GUI datasets are available upon application to the ISSDA in Ireland.

DIGITAL ENGAGEMENT AND PSYCHIATRIC SYMPTOMS 2.

Declaration of competing interest

Authors have no Conflicts of Interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2022.107290.

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