Watching the watchers: assessing the nature and extent of children's screen time using wearable cameras

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ABSTRACT

AIM: Children's screen use has increased rapidly in recent years, yet little is known about this use in real-time due to reliance on self-report or proxy data sources. Screens provide benefits such as educational content and social connection, but also pose health risks including obesity, depression, poor sleep and poor cognitive performance. In this cross-sectional observational study, we aimed to determine the nature and extent of children's after-school screen time using wearable cameras.

METHOD: Children aged 11–13 years took part in the New Zealand Kids'Cam project in 2014/2015. Each child wore a camera that passively captured images of their surroundings every 7 seconds. Images from 108 children were manually coded.

RESULTS: Children spent over a third of their time on screens, including over half their time after 8pm. Television accounted for the highest proportion of screen time (42.4%), followed by computers (32.0%), mobile devices (13.0%) and tablets (12.6%). Approximately 10% of children's screen time involved multiple screen use.

CONCLUSION: Guidelines are needed to promote healthy screen time behaviour among children. Further research is also needed to monitor the impact of screens on children's wellbeing, including any socio-demographic differences, and to identify innovations to protect children from harm in the online space.

Children use a variety of screens in their daily lives, including mobile devices, computers, tablets and televisions. Such use may present both risks and benefits for their health and development.[1] Evidence from systematic reviews suggests that higher time spent on screens (all types combined) is associated with obesity, unhealthy diets, depressive symptoms, shorter and poorer quality sleep and poor cognitive performance.[2–6] More recently, the "fear of missing out" on things including social media access has emerged as a key driver of problematic screen use among adolescents, which (in turn) may have consequences for their mental health and wellbeing.[7–9] In addition, children's exposure to bullying on social media is of substantial concern.[10–12] Potential benefits of screen use may arise from opportunities to socialise and access to age-appropriate educational content,[13,14] although evidence of positive health impacts from systematic reviews has been inconsistent.[2] Screen use increased rapidly during the COVID-19 pandemic,[15] highlighting the need for contemporary methods to keep pace with technological developments and changing patterns of children's screen use.

Owing to the health risks associated with screen time, several countries and health organisations have issued guidelines on children's screen use. However, the contents of these guidelines vary. The World Health Organization (WHO) recommends screen time restrictions for children under age 5, but currently has no guidelines for older children and adolescents.[16] Some countries, including New Zealand, recommend that children and adolescents (outside school time) spend no more than 2 hours per day on screens.[17,18] Guidelines from other countries have offered more general advice rather than time limits, including recommendations to consider screen types and activities, and children's age and stage of development.[19–21]

To help inform policy to promote healthy screen use behaviour, researchers need reliable and accurate measures of screen activity. A weakness in the screen time literature has been a lack of data on non-television media (e.g., computers, smartphones and tablets)[2] and reliance on self-report methods or parent proxies to measure screen use. For example, Scharkow[22] found that, among 3,401 people aged 14–80 from individual United States households, self-report measures have poor accuracy for determining internet use compared with recorded logs of online activity. While Scharkow's study participants kept a log

record of their screen use, there are limitations associated with recorded logs, owing to high participant burden and the possibility that brief or reflexive uses are missed.[23] Multi-screen use—that is, the use of two or more media devices simultaneously, such as a TV and laptop or a handled device—is a growing phenomenon that may carry additional health risks than single-screen activity (e.g., poorer sleep quality),[24,25] yet few studies have evaluated multi-screen activity.

Wearable cameras offer a valuable opportunity to explore screen time behaviours. These devices capture images of the wearer's surroundings at fixed intervals (typically several images per minute). A pilot study of 15 adolescents from New Zealand aged 13–17 found that wearable cameras provide a feasible, acceptable method of measuring pre-bedtime screen behaviour, including multi-screen activity.[26] Given this background, we aimed to use wearable cameras to examine the extent (duration and frequency of use) and nature (types of screens, activities and when used) of children's screen time during the after-school period, using data collected in the 2014/2015 Kids'Cam project.[27] Kids'Cam was a cross-sectional observational study that recruited 168 randomly selected children, aged 11–13 years from 16 randomly selected schools in the Wellington Region of New Zealand.[27]

Methods

The Kids'Cam project

The study was conducted over a 12-month period (July 2014 to June 2015) to account for seasonal differences in the participants' environments and activities. Sampling was stratified by school decile and child ethnicity to enable equal explanatory power for socio-economic and ethnic subgroups. Each child was provided with a wearable camera (Autographer) and a GPS device (Qstarz BT-Q1300ST Sports Recorder). Children were instructed to wear the devices for 4 consecutive days (2 school and 2 weekend days) on lanyards around their necks. Children were asked to wear the devices for all waking hours, but to remove the camera in situations where privacy could be expected, if they felt uncomfortable, when swimming or playing vigorous sport, or if requested by others.[27] Ethical approval was obtained to study all aspects of children's lives relevant to public health from the University of Otago Human Ethics Committee (Health) (13/220). Further methodological details are published elsewhere.[27]

In this ancillary study of children's screen time, we included 108 Kids'Cam participants (64.3% of total sample) who captured at least 30 minutes of image data on Thursday afternoons after school. The after-school period was selected because it accounts for the largest proportion of children's weekday recreational time. Of the 2 weekdays on which data were collected—Thursday and Friday—Thursdays were chosen as being the most like usual weekdays; after-school behaviours often differ on Fridays, being the end of the school week.

Coding for screen time

A coding protocol was developed to guide the coding of children's screen time (Appendix 1). Screen time was defined as the duration of time spent engaged with a screen. The coding process differentiated between screen mediums (i.e., type of screen) and screen activities, as detailed below. Codes were "tagged" to each image using customised software. Prior to coding, a reliability test was conducted using a test dataset of five participants (n=4,279 outside school images), on which three coders (one of whom coded all the data) achieved 90% or more agreement.

Screen mediums included televisions, computers, tablets and mobile devices (full definitions are available in Appendix 1). Multiple screen use was defined as the use of any two or more screen mediums in an image, e.g., watching television while playing on a tablet. Screen activities included programmes, games, social activities (e.g., social media), internet, background, "other" and undetermined (Appendix 1). Background activity included situations where a screen was present in a child's vicinity, but the child did not appear to be fully engaged with it (e.g., they were facing away or doing something else). This generally applied to television, where children could still be influenced by the screen (e.g., through hearing advertising). "Other" was defined as any other type of screen-based activity, such as listening to music through a screen device or using productivity software such as Microsoft Word. Activities were coded as undetermined in situations where it was clear that the child was engaging with a screen, but the coder was unclear what was occurring on the screen; for example, due to obstruction of the screen in the image (e.g., food), interference of light or other image quality issues.

Statistical analysis

Statistical analyses were performed in Stata IC/16. Rates of screen time/hour (presented as means with 95% CIs) were calculated with negative binomial regression, using counts of screen time images as the numerator and total images captured as the denominator. Images were specified as contributing 7 seconds of recording time (this being the median interval between images). Analyses accounted for the stratified sampling design using Stata's svy command and associated weighting options, to better reflect the target population. Subgroup differences in screen time were examined with rate ratios (from the negative binomial models), mutually adjusting for: ethnicity, gender and socio-economic deprivation (New Zealand Individual Deprivation Index [NZiDep])[28] simplified to lower deprivation (NZiDep groups 1, 2 and 3 and higher deprivation (NZiDep groups 4 and 5) and body weight status according to Cole cut-offs: overweight/obese (BMI >25.0) and non-overweight (BMI <24.9).[29] Weight status was included given the evidence demonstrating an association between screen use and increased risk of unhealthy weight gain owing to greater sedentary behaviour/reduced physical activity, passive overconsumption and exposure to the marketing of unhealthy food.[30,31] Participants with unknown weight status (n=4) and socio-economic deprivation (n=3) (Table 1) were excluded from these comparisons.

Results

Sample characteristics

The characteristics of the 108 children are shown in Table 1. Just over half (56%) were female and 44% were overweight/obese children, which reflects the national statistics for children of this age at the time of the study. The ethnic distribution was 43% NZ European, 35% Māori and 22% Pacific (reflecting the stratified sampling design). There were more than twice as many children in the lower socio-economic deprivation group (70%) than the higher socio-economic deprivation group (28%).

Children captured a median of 2.0 hours' (interquartile range [IQR]: 1.4, 2.9) worth of images over the observation period, of which 95.8% were codable for screen activities. There was some variation in image capture across groups (Table 1), with children of higher socio-economic deprivation capturing fewer images than children of lower socio-economic deprivation.

Screen time

Children's mean rate of screen time was 23.1 minutes/hour, which included 2.3 mins/hour of multi-screen use (10.0% of total). Televisions accounted for the highest proportion of screen time (9.8 mins/hour; 42.4% of total), followed by computers (7.4 mins/hour; 32.0% of total), mobile devices (3.0 mins/hour; 13.0% of total) and tablets (2.9 mins/hour; 12.6% of total) (Table 2). Image examples of screen types and screen activities are shown in Figure 1.

Differences by key demographic groups are presented in Table 2. Females spent just over half as much time on screens (total screen time) (rate ratio [RR]=0.58, 95% CI 0.37–0.93) and a fifth of the time on computers (RR=0.19, 95% CI 0.04–0.85) than males. Total screen time was similar for Māori, NZ European and Pacific children (Table 2), though there were some differences by ethnicity in television viewing (relative to NZ European: RR for Pacific=2.10, 95% CI 1.14–3.87; RR for Māori=1.38, 95% CI 0.95–2.00). There were some patterns of screen time according to deprivation. Although total screen time was similar by deprivation, there was evidence that high deprivation children spent less screen time on computers (RR=0.17, 95% CI 0.05–0.54) and mobile devices (RR=0.33, 95% CI 0.14–0.75) relative to those of low deprivation. There was no strong evidence for patterning of screen time use according to overweight status (total screen time RR=0.76, 95% CI 0.46–1.23 for overweight/obese compared to not overweight group).

Screen activities

Of the screen activity categories (Appendix Table 1), watching programmes accounted for the highest proportion of total screen time (6.3 mins/hour; 27.0% of total), followed by games (5.6 mins/hour; 23.9% of total), other (3.3 mins/hour; 14.0% of total), background (3.0 mins/hour; 12.8% of total), social activities (1.8 mins/hour; 7.8% of total) and internet (1.6 mins/hour; 6.9% of total). On average, 1.3 minutes of screen activities were coded as "unknown" (7.7% of all screen time). 10 times lower rates of screen use for games were observed among girls (relative to boys) (RR=0.10, 95% CI 0.03–0.30) and games were used more than half as often by overweight children (relative to non-overweight children) (RR=0.31, 95% CI 0.10–1.00). Children of higher deprivation spent less time engaged in "other" screen activities than children of lower deprivation (RR=0.16, 95% CI 0.04–0.57).

Rates of screen use were highest in the late evening period (after 8 pm, mean of 37.7 mins/

Table 1: Participant characteristics of Kids'Cam Screen sample.

Characteristic	Frequency (unweighted %)	Median recording hours, unweighted (IQR)	Mean recording hours, weighted (95% CI)
Total sample	108 (100)	2.0 (1.4, 2.9)	2.2 (1.9, 2.5)
Gender			
Female	60 (56)	1.9 (1.1, 2.8)	2.4 (2.1, 2.6)
Male	48 (44)	2.3 (1.6, 3.0)	2.1 (1.6, 2.6)
Overweight status			
Not overweight	56 (54)	2.3 (1.5, 2.8)	2.3 (2.0, 2.7)
Overweight/obese	48 (46)	1.8 (1.2, 2.9)	2.0 (1.6, 2.5)
Ethnicity			
NZ European	46 (43)	2.6 (1.7, 2.9)	2.3 (2.0, 2.7)
Māori	38 (35)	1.7 (1.0, 2.7)	1.9 (1.4, 2.4)
Pacific	24 (22)	1.9 (1.7, 2.9)	2.0 (1.7, 2.4)
Socio-economic deprivation			
Low deprivation	75 (71)	2.5 (1.6, 3.0)	2.3 (2.0, 2.6)
High deprivation	30 (29)	1.7 (1.0, 2.5)	1.8 (1.5, 2.1)

Four missing age and three missing socio-economic deprivation.

hour) than in the early evening period (5:30 pm–8 pm, mean of 24.6 mins/hour) and early afternoon period (3 pm–5:30 pm, mean of 20.6 mins/hour) (Table 4). Higher rates of screen time closer to bedtime was predominantly explained by television use (26.3 mins/hour in the late evening; 69.7% of screen use), compared with 11.6 min/hour (46.9% of screen use) in the late evening and 6.6 mins/hour (32.1% of screen use) in the early afternoon (Table 4).

Discussion

Children in this study used screens, on average, for over one third of the after-school period, including over half the time after 8 pm. Television accounted for the highest proportion of screen time, which is consistent with previous studies,[32] although it is possible that screen use patterns have changed since this data was collected in 2014/2015. The high rate of screen activity raises health concerns as it likely displaced other activities such as active play and sleep.[33] In addition, it is particularly problematic given the risk of exposure to cyberbullying.[10–12] The incidence of bullying on social media is particularly high among New Zealand children, with more than one in four parents reporting that their child had experienced cyberbullying.[10] High rates of screen time after 8 pm raised particular concerns for children's sleep hygiene; that is, practising behaviours that facilitate sleep and avoiding behaviours that interfere with sleep, given that national and international evidence demonstrate pre-bedtime screen use is associated with poor sleep outcomes.[5,6] Furthermore, the most popular screen activities (programmes and gaming) may have limited the opportunities for learning or development relative to other activities the children could have engaged in.

We found that children engaged in multi-screen activity 10% of the time while using screens, which is higher than 5% reported among a pilot study of adolescents aged 13–17.[26] Qualitative research suggests that children may use multiple

Table 2: Mean screen time in minutes per hour and mutually adjusted rate ratios for subgroup differences, by screen medium, including all screen mediums combined.

	All screens	Rate ratio (95% CI)[a]	Television	Rate ratio (95% CI)[a]	Computer	Rate ratio (95% CI)[a]	Mobile device	Rate ratio (95% CI)[a]	Tablet	Rate ratio (95% CI)[a]
	Mean (95% CI)		Mean (95% CI)		Mean (95% CI)		Mean (95% CI)		Mean (95%CI)	
All participants	23.1 (100)	-	9.8 (42.4)	-	7.4 (32.0)	-	3.0 (13.0)	-	2.9 (12.6)	-
Gender										
Males	29.5 (100)	1 (Reference)	9.7 (33.0)	1 (Reference)	11.9 (40.3)	1 (Reference)	4.3 (14.6)	1 (Reference)	3.4 (11.5)	1 (Reference)
Females	16.5 (100)	0.58 (0.37–0.93)	9.9 (60.4)	1.02 (0.59–1.76)	2.3 (13.8)	0.19 (0.04–0.85)	1.6 (9.7)	0.37 (0.11–1.30)	2.3 (14.0)	0.68 (0.18–2.52)
Overweight status										
Not overweight	25.6 (100)	1 (Reference)	9.9 (38.7)	1 (Reference)	9.7 (37.9)	1 (Reference)	2.8 (11.0)	1 (Reference)	3.0 (11.6)	1 (Reference)
Overweight/obese	20.7 (100)	0.85 (0.53–1.36)	9.6 (46.5)	0.97 (0.71–1.34)	4.0 (19.2)	0.41 (0.15–1.14)	3.8 (18.3)	1.34 (0.42–4.31)	3.0 (14.4)	1.01 (0.26–3.82)
Ethnicity										
NZ European	22.9 (100)	1 (Reference)	8.3 (36.2)	1 (Reference)	8.1 (35.3)	1 (Reference)	3.2 (14.1)	1 (Reference)	3.1 (13.4)	1 (Reference)
Māori	24.3 (100)	1.11 (0.79–1.57)	11.5 (47.2)	1.38 (0.95–2.00)	6.9 (28.5)	0.85 (0.24–3.09)	3.4 (13.9)	1.05 (0.62–1.77)	2.4 (9.7)	0.77 (0.22–2.63)
Pacific	25.5 (100)	1.18 (0.72–1.94)	17.4 (68.3)	2.10 (1.14–3.87)	3.7 (14.5)	0.46 (0.11–1.97)	1.5 (5.8)	0.46 (0.16–1.31)	2.4 (9.4)	0.78 (0.32–1.87)
Deprivation										
Low	24.4 (100)	1 (Reference)	9.5 (39.0)	1 (Reference)	8.6 (35.4)	1 (Reference)	3.4 (14.1)	1 (Reference)	2.6 (10.8)	1 (Reference)
High	18.3 (100)	0.75 (0.46–1.23)	10.8 (59.2)	1.14 (0.69–1.86)	1.4 (7.9)	0.17 (0.05–0.54)	1.1 (6.2)	0.33 (0.14–0.75)	4.1 (22.7)	1.57 (0.74–3.34)

[a]Mutually adjusted for gender, overweight status, ethnicity and deprivation.

Table 3: Mean screen time in minutes per hour and mutually adjusted rate ratios for subgroup differences by screen activity.

	Pro-grammes	Rate ratio (95% CI)[a]	Games	Rate ratio (95% CI)[a]	Social	Rate ratio (95% CI)[a]	Internet	Rate ratio (95% CI)[a]	Back-ground	Rate ratio (95% CI)[a]	Other	Rate ratio (95% CI)[a]
	Mean (%)		Mean (%)		Mean (%)		Mean (%)		Mean (%)		Mean (%)	
All participants	6.3 (27.0)	-	5.6 (23.9)	-	1.8 (7.8)	-	1.6 (6.9)	-	3.0 (12.8)	-	3.3 (14.0)	-
Gender												
Males	5.2 (17.7)	1 (Reference)	9.7 (32.8)	1 (Reference)	2.6 (8.8)	1 (Reference)	2.1 (7.0)	1 (Reference)	4.0 (13.4)	1 (Reference)	4.0 (13.5)	1 (Reference)
Females	7.5 (45.8)	1.45 (0.79–2.65)	0.9 (5.6)	0.10 (0.03–0.30)	1.0 (5.8)	0.37 (0.03–4.32)	1.1 (6.9)	0.55 (0.13–2.39)	1.9 (11.5)	0.48 (0.17–1.35)	2.5 (15.0)	0.62 (0.15–2.59)
Overweight status												
Not overweight	6.3 (24.6)	1 (Reference)	7.4 (29.0)	1 (Reference)	0.8 (3.2)	1 (Reference)	1.9 (7.6)	1 (Reference)	3.0 (11.9)	1 (Reference)	4.0 (15.5)	1 (Reference)
Overweight/ obese	5.9 (28.6)	0.94 (0.63–1.40)	2.8 (13.5)	0.38 (0.20–0.71)	3.9 (18.7)	4.67 (0.91–23.94)	1.2 (5.6)	0.60 (0.16–2.29)	3.1 (14.9)	1.01 (0.30–3.44)	2.3 (11.3)	0.59 (0.23–1.52)
Ethnicity												
NZ European	5.3 (23.1)	1 (Reference)	6.0 (26.2)	1 (Reference)	1.9 (8.5)	1 (Reference)	1.6 (7.1)	1 (Reference)	2.6 (11.4)	1 (Reference)	3.8 (16.5)	1 (Reference)
Māori	9.0 (37.1)	1.71 (0.94–3.09)	5.2 (21.5)	0.87 (0.24–3.16)	2.1 (8.6)	1.07 (0.23– 4.95)	1.8 (7.5)	1.11 (0.31–3.96)	2.0 (8.4)	0.78 (0.21–2.87)	2.1 (8.5)	0.55 (0.12–2.51)
Pacific	9.3 (36.4)	1.76 (0.80–3.84)	3.5 (13.6)	0.58 (0.20–1.69)	0.8 (3.0)	0.39 (0.07–2.37)	1.3 (5.2)	0.81 (0.11–6.25)	6.5 (25.6)	2.50 (0.66–9.40)	1.5 (6.1)	0.41 (0.04–4.16)
Deprivation												
Low	5.8 (23.6)	1 (Reference)	6.3 (25.9)	1 (Reference)	1.7 (7.0)	1 (Reference)	1.8 (7.3)	1 (Reference)	3.1 (12.7)	1 (Reference)	3.8 (15.7)	1 (Reference)
High	8.5 (46.6)	1.48 (0.74, 2.96)	2.0 (10.8)	0.31 (0.10–1.00)	2.6 (14.1)	1.51 (0.57–4.03)	0.8 (4.1)	0.42 (0.08–2.24)	2.3 (12.9)	0.76 (0.21–2.71)	0.6 (3.3)	0.16 (0.04–0.57)

[a]Mutually adjusted for gender, overweight status, ethnicity and deprivation.

Table 4: Mean minutes per hour of screen use in the early afternoon, early evening and late evening (with % of screen time)

Screen use	Early afternoon (3 pm–5:30 pm)	Early evening (5:30 pm–8 pm)	Late evening (after 8 pm)
All screens	20.6 (100.0)	24.6 (100.0)	37.7 (100.0)
Television	6.6 (32.1)	11.6 (46.9)	26.3 (69.7)
Computer	7.0 (33.9)	8.4 (34.2)	7.2 (19.0)
Mobile	3.7 (17.8)	2.4 (9.8)	1.7 (4.4)
Tablet	3.3 (16.2)	2.2 (9.1)	2.6 (6.9)

Figure 1: (Top left) programme on television; (top right) gaming on computer; (bottom left) social activity on mobile device; (bottom right) multi-screen activity with unknown activity on mobile device and programme on television.

screens for several reasons, including tempering impatience while a device is loading, filtering out unwanted advertising and because it is enjoyable.[24] A recent review found limited research on multiple screen use in the literature,[2] although there is some evidence that multiple screen use is associated with poorer sleep quality than single screen use.[25]

While we found no associations by bodyweight, we found several patterns in screen use by other socio-demographic characteristics, which are largely consistent with previous studies. These include: higher rates of total, computer and gaming screen time among boys than girls[35] lower computer use among children of higher deprivation, consistent with their lower access to computers;[36] and higher rates of television use among Pacific[6] and Māori children than NZ European children.[37] The differences by ethnicity and socio-economic deprivation add to previous concerns about "digital divides", characterised by differences in the nature of digital screen access by deprivation.[38] A surprising finding was more screen time on tablets among children of high deprivation than those of low deprivation, which may be explained by the lower cost of these devices compared to computers.

Our study identifies some strengths of wearable cameras for assessing screen time, which echo some of Smith et al.'s pilot study findings.[26] The method enabled the recording of children's screen use as they went about their day, potentially making this one of the first studies to do so. Differentiating between screen activities is important given evidence that the type of activity affects health outcomes.[1] The passive method of data collection also minimizes participant burden. This is particularly important for capturing mobile device use, which often occurs for brief periods of time and is likely under-reported in previous research. It also enables the study of any screen device that is in front of the child. However, cameras cannot determine where children are directing their attention. This presents a challenge for identifying children's engagement with "background" screens (e.g., televisions). Correctly identifying these activities may therefore require wearable cameras to be used alongside other methods, e.g., self-report or activity logs. The coding of images is also time intensive. While automated image recognition could expedite coding of some visual elements, this is less feasible for the variable nature of screen activities.

As well as the strengths of wearable cameras identified above, a key strength of this study was the high rate of image capture. Cameras worn in the Kids'Cam project captured images of children's surroundings approximately every 7 seconds, which was more than twice as frequent as previous research.[26] This likely yields a more accurate measure of brief bouts of screen activity (e.g., mobile phone use). Further, the sample size of 108 was considerably larger than previous research,[26] helping to identify the utility of this methodology on a larger scale.

The study has some limitations. It is possible that the 2014/2015 dataset may not accurately reflect current trends in screen type usage and screen activities, particularly since the COVID-19 pandemic. Our sample was limited to children of Māori, Pacific or NZ European ethnicity. To gather more comprehensive information, future studies should be designed to include New Zealand's other ethnic groups. As the cameras captured a median of 2 hours after school, we only recorded approximately a quarter of children's after-school time. Also, because we excluded 60 children with fewer than 30 minutes of image data, we do not know their use. Nevertheless, for the majority of children in the study, it is possible to see the nature of their screen use and determine that screens play a dominant role in the children's lives.

Conclusions

In this study, wearable cameras were used to explore the nature and extent of children's screen time. The approach enabled an objective and reliable assessment of screen activity across all types of screens, including multi-screen activity. Children in the study spent over one third of their after-school time using screens, with higher rates of screen time in the late evening period (after 8 pm). Most screen use involved watching programmes and gaming. The high rate of recreational screen time, including pre-bedtime, reinforces the need for consistent guidelines to promote healthy screen time behaviour among children. Further research is needed to monitor the impact of screens on children's wellbeing, including any socio-demographic differences, and for innovation in protecting children from harm in the online space.

COMPETING INTERESTS
Nil.

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Appendix 1: Kids'Cam Screens Annotation Manual—Image data

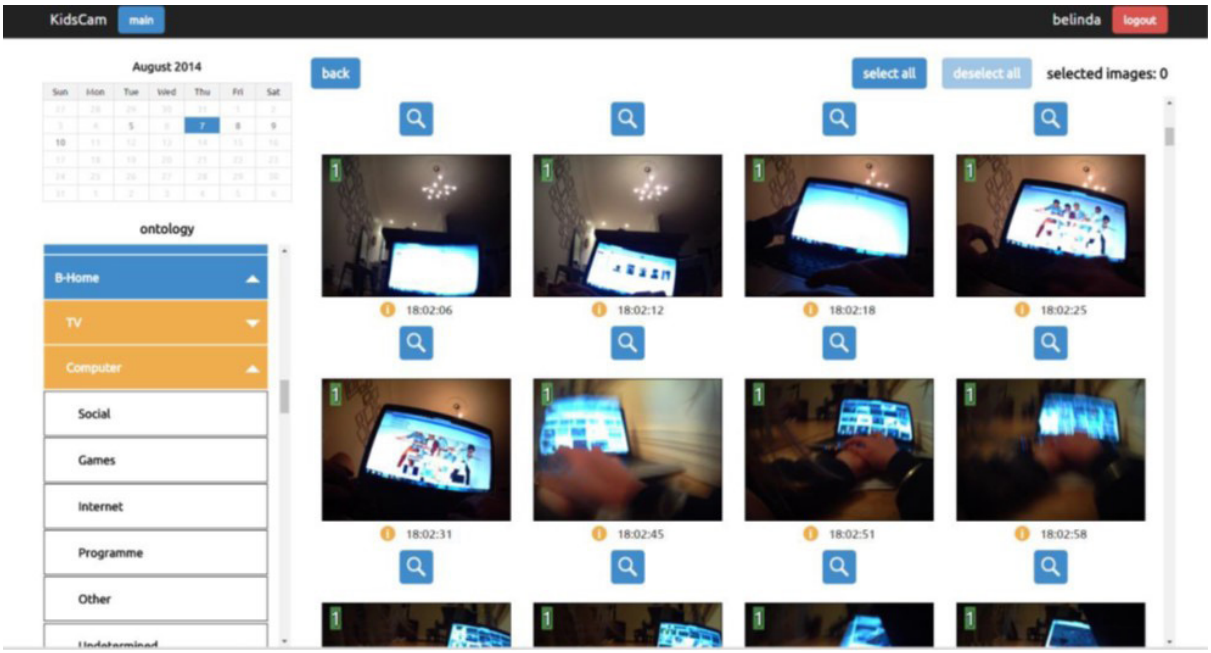
Research questions:

- What is the nature and extent of children's screen time during the after-school period on a typical weekday?
- What is the association between children's after school screen time, type and activity, and children's body weight, gender, ethnicity and socio-economic deprivation?

Annotation overview

The development of the annotation schedule for Kids'Cam Screens was based on observations made during scoping research. It was further informed by the annotation protocols the Kids'Cam food marketing project (hereafter Kids'Cam), and other projects that used wearable cameras (Barr et al., 2015; Doherty et al., 2012; Gemming et al., 2013). The bespoke software developed by Dublin City University for Kids'Cam was adapted for use in Kids'Cam Screens. It required a three-tiered, "tree" > "branch" > "leaf" annotation scheme. An example of the software is shown in Figure 1. The left panel shows the three-tier annotation panel, while images for each hour are shown on the right. A calendar can be seen in the top left corner to navigate day and date of the images shown. Images captured during the designated time period from every eligible participant totalled 120,780. Every image was reviewed for the instance of a screen, the screen type and activity carried out, and annotated accordingly. For Kids'Cam Screen Time the three-tiered annotation scheme of "setting" > "screen type" > "activity" was used.

Figure 1: Example of annotation software interface.



Study definitions

Table 1: Kids'Cam Screens setting annotations and corresponding definitions.

Setting	Definition
Home	Includes all spaces within the home gates and boundaries i.e., indoor and outdoor spaces; or someone else's home
Community venue	Library Recreation centre/community hall— a public space where meetings are held Marae—includes the meeting house, dining hall, education and associated facilities and residential accommodation associated with the marae Church
Street	On the street, outside private property or a community venue or retail store
Food retail	A retail store that sells food. Includes supermarkets, cafes, bakeries, etc.
Other retail	General product retailers whose primary purpose is something other than food retail
Outdoor recreation space	Parks—characterised by the presence of large, open, grassed spaces, possibly with some equipment such as climbing frames or playgrounds (not primarily used for organised sport) Walking track—characterised by in-bush or off-road areas such as the town belt Beach River
Private transport	Inside a car, van or truck
Public transport—facility	Associated with public transport facilities—e.g., bus shelters, train stations, airports etc.
Public transport—vehicle	Inside a bus, train, airplane, ferry

Table 2: Screen categories and corresponding definitions.

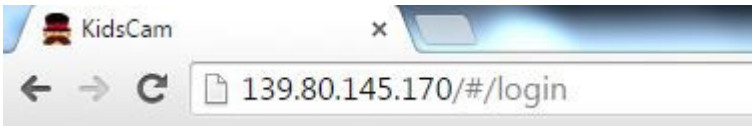
Medium	Definition
Television (TV)	Generally an electronic screen that could stand alone, or mounted to the wall
Computer	Includes desktop computer and laptops
Tablet	An electronic screen that does not require a keyboard or mouse, most commonly used for surfing the internet and running applications: e.g., iPads or Samsung Galaxy tablets
Mobile device	A handheld device, most commonly used for surfing the internet and running applications. Includes smart phones and iPods

Table 3: Screen-based "activity" annotations and corresponding definitions for Kids'Cam Screen Time.

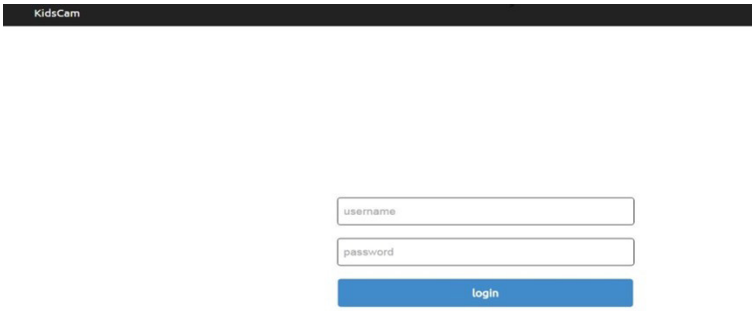
Activity	Definition
Programme	Watching any form of programme or movie; this activity was most common on a television screen
Games	Content of the screen appeared to present some goal or objective, with rules and restrictions around obtaining it
Social	Activities that involved interacting with others. Encompassed activities such as Facebook, Instagram, Snapchat, text-messaging, etc., and were most often carried out on mobile devices, tablets and computers
Internet	Using websites other than those used for social or gaming activity; included online shopping and watching videos on YouTube
Background	When a screen was present in the child's immediate vicinity; however, the child did not appear to be fully engaged with it, but could still be influenced by it
Other	During the scoping study it was determined that an "Other" annotation would be required to describe any screen-based activity other than those described above, such as listening to music on iTunes, or running offline programmes such as Microsoft Word and Microsoft PowerPoint
Undetermined	Images where it was clear the child was engaging with a screen (see page 80), but the annotator was uncertain what was occurring on the screen: this situation most commonly occurred due to an interference of light

Logging in as User

1) Type in the Kids'Cam URL (http://139.80.145.170) into the web browser (*Google Chrome)* of a computer connected to the University of Otago Server.

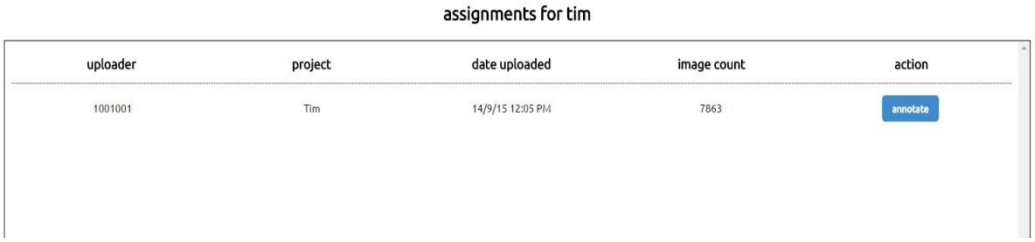


2) Type in your username and password to access the photos you have been personally assigned.

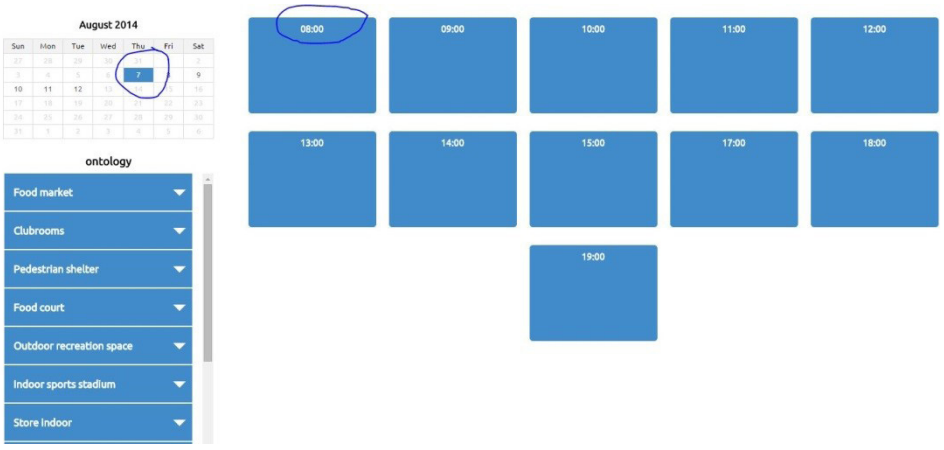


Accessing photos

1) Once logged in, your assignments will appear. In order to access a participant's photos click on the annotate button.

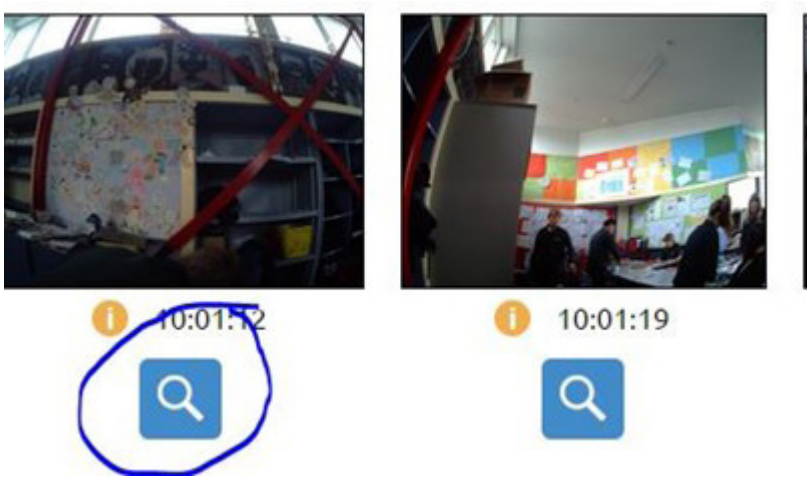


2) Next click on the date you are interested in using the calendar function and then select the time by clicking on the appropriate hour.

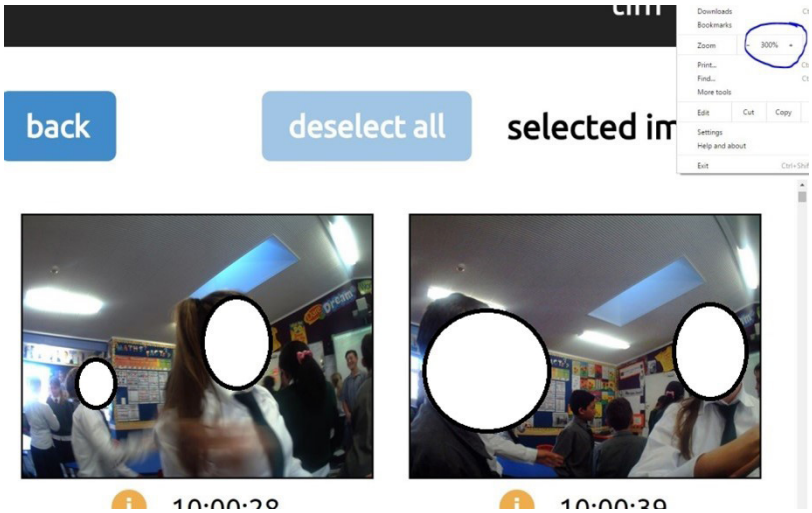


Annotating an image

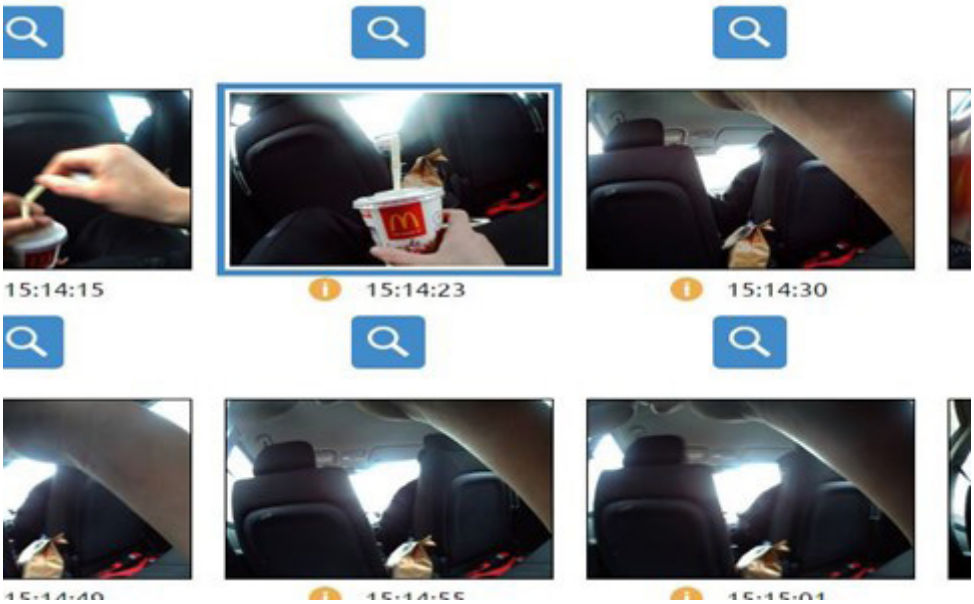
1) Annotations must be made after having magnified the image by clicking the magnify function. Further magnification is permitted if necessary by clicking on the image once. The image will appear in a new tab fully magnified.



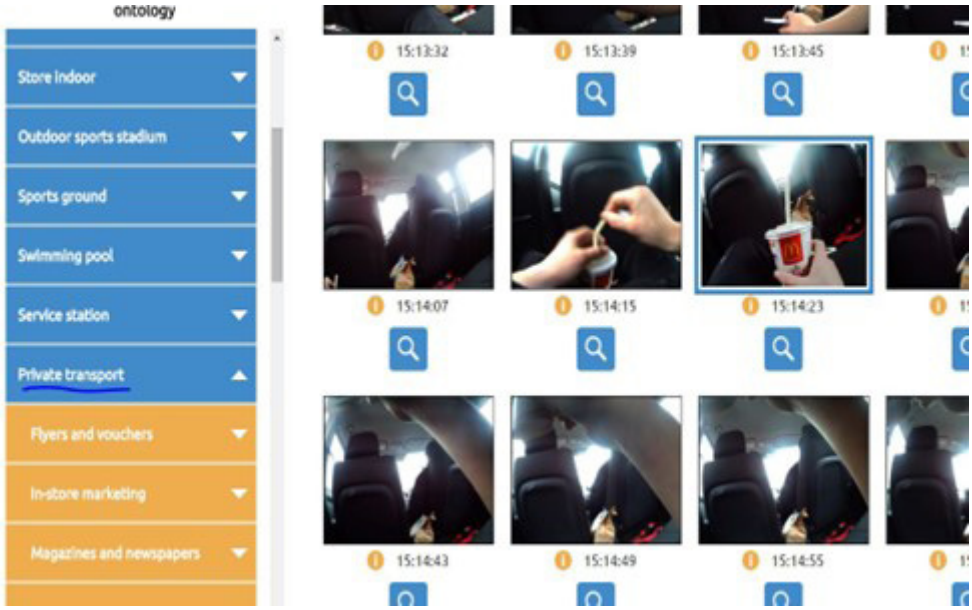
2) Alternatively, you can zoom in 300%; then the thumbnails become the same size as a magnified image and magnification is not required in order to code.



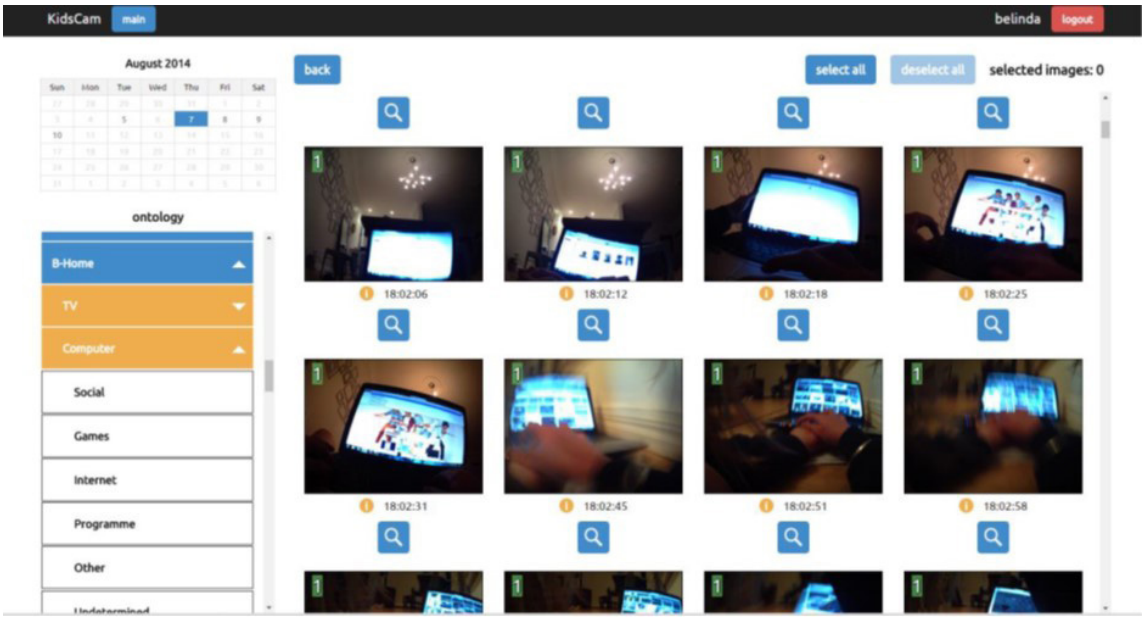
3) In order to annotate an image you **must click out of the magnified image** and click on the image you wish to annotate. Selection is symbolised by the blue border.



4) Annotators are to code images in the following sequence:
Setting > Screen type > Screen activity
5) First the image must be coded for setting (see setting definitions) using the annotation ontology bar to the left of your screen.

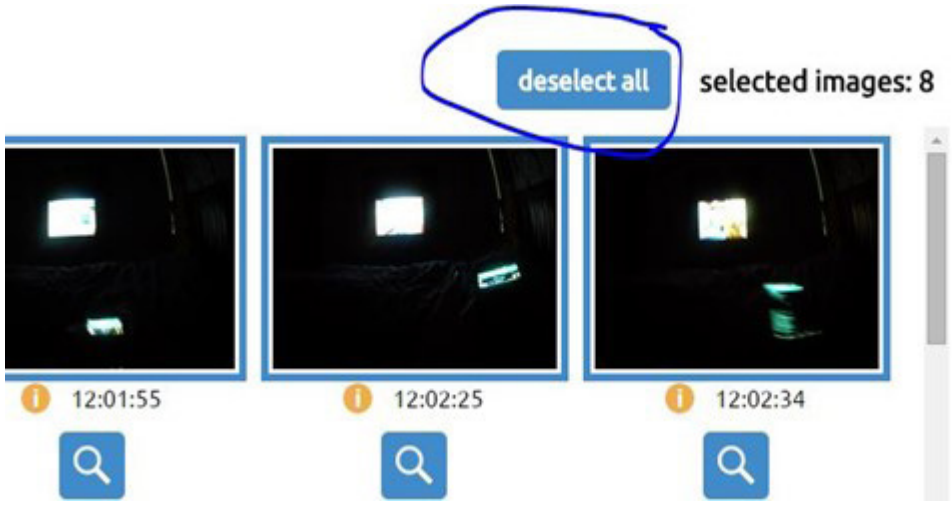


6) Once setting is selected, the ontology will open up a selection of screen types. Once determined (see definitions) select the appropriate screen type.



7) Once the screen type is selected a range of screen activities will appear. Once determined (see definitions) select the appropriate activity and the photo will be annotated. A green marker will appear to inform you the image has been annotated.

8) Make sure you deselect the images before making another annotation by hitting the “deselect” button.



9) To delete an annotation, select the photos you want to remove the annotations from. Then pull curser over highlighted ontology level and a red X will appear. Click the X.

Multiple screen use

Multiple screen use is defined as the use of any two or more screen mediums in an image, e.g., watching television while playing on a tablet. Figure 2 shows an example of a child using two screen types simultaneously.

Figure 2: Example of an image that would be annotated as "Home" > "Television" > "Programme" and "Home" > "Mobile Device" > "Unknown".

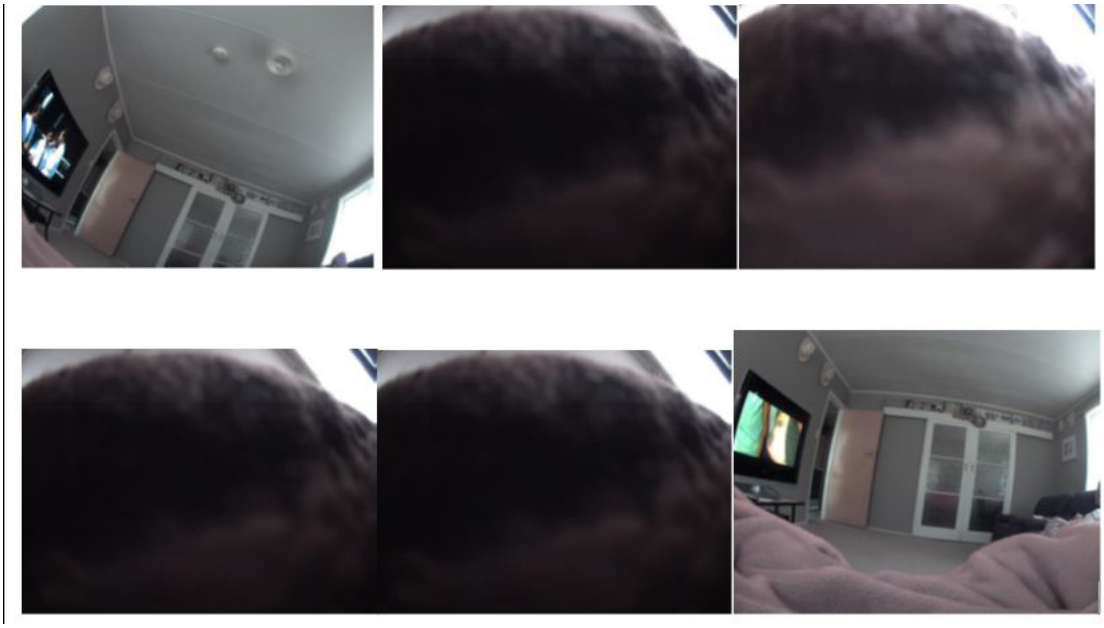
Blurry and blocked images

During the scoping study, it was observed that within a sequence of images containing a screen, some images were completely blocked. Such instances occurred when, for example, the participant was watching television, the camera flipped and images were taken while the camera was lying flat against the child's torso, or the camera fell behind a blanket or sweatshirt. In the event of a completely blocked image, the 18-image rule was devised to ensure consistency throughout the analysis process.

The 18-image rule states that a series of fully blocked images can be counted as screen time if the images before and after the blocked image show a screen, and that no more than 18 images (approximately 2–3 minutes) occur in between. If more than 18 blocked images occur between two images with screens, the blocked images cannot be included as screen time; they are also removed from total time. The rule, and the choice of 18 images, was based on previous wearable camera research. The SenseCam Coding Manual produced by The University of California, San Diego, USA, used a 10-image rule (the equivalent of 3 minutes, given reduced image-taking frequency of the cameras used in the study) when coding for physical activity and environment. The authors thought 3 minutes was justified, as a change in context or environment is unlikely in that time period (Doherty et al., 2012).

The images in Figure 3 illustrate how the 18-image rule was implemented for fully blocked images in Kids'Cam Screen Time. The first image shows that the child is watching television. In the two following images, the camera has fallen behind a blanket, and thus the annotator cannot be certain that the child is still watching the television. However, the subsequent images show the television in plain sight again. In this instance, all four images would be annotated as "Home" > "Television" > "Programme". If, however, 19 or more images elapsed between the images in which the television is seen, the blocked images would be annotated as "Uncodable", and also excluded from total time. The argument for the 18-image rule is that even if the television was obstructed for up to 18 images (2–3 minutes), if an image showing the screen on appears subsequently, it is unlikely the screen was switched off.

Figure 3: Series of 6 images that would all be annotated 'Home' > 'Television' > 'Programme'.



Computers

1) Images are only to be coded using an external computer screen no larger or smaller than 22'. Do not code using a laptop screen or the Kids'Cam server screen.

2) **Always** use the *Google Chrome* internet browser to access and analyse the images, as the annotation framework has been optimised for this platform.

Data analysis rules

For images that are separated by less than 1 second, the first image will be counted towards the data analysis. Any subsequent images within the 1-second time lapse will be removed from the analysis.

Ethics

1. Keep the identifiable features of the data **confidential;** these features of the data should not be discussed with anyone outside the research team.

2. Do not leave data or equipment containing unsecured data unattended. If you leave your computer for any amount of time you must **log out.**

3. The University of Otago possesses ownership of all image data. Applicants cannot copy data without the written approval of the Principal Investigator or retain copies of the data after completion of work. Any data copied or released must be stored on a password-protected device and must have gone through the appropriate anonymised procedure.

4. Protect the anonymity of all participants, third parties and their environments. To protect the privacy of those who may be inadvertently captured in the images, all images used in disseminated material will have identifiable people, street names, places, retail outlets, businesses and school names blurred. The demographic information collected will only be viewed by the core Kids'Cam team.

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