‘Treat me as your friend, not a number in your database’: Co-designing with Children to Cope with Datafication Online

Ge Wang
ge.wang@cs.ox.ac.uk
Department of Computer Science. University of Oxford
Oxford, UK

Jun Zhao
jun.zhao@cs.ox.ac.uk
Department of Computer Science. University of Oxford
Oxford, UK

Max Van Kleek
max.van.kleek@cs.ox.ac.uk
Department of Computer Science. University of Oxford
Oxford, UK

Nigel Shadbolt
nigel.shadbolt@cs.ox.ac.uk
Department of Computer Science. University of Oxford
Oxford, UK

ABSTRACT

Datafication refers to the practices through which children’s online actions are pervasively recorded, tracked, aggregated, analysed, and exploited by online services in ways including behavioural engineering and monetisation. Previous research has shown that not only do children care significantly about various aspects of datafication, but they demand a chance to take action. Through 10 co-design sessions with 53 children, we examined how children in the UK want to be supported to cope with the datafication practices. Our findings provide insights for creating age-appropriate support for children’s algorithmic literacy development, highlighting and unpacking the importance of no one-size-fitting-all designs to support children’s coping with datafication. We contribute a first understanding of how children aged 7–14 would like to be supported with datafication and what future data-driven digital experiences should be like for them, who demand a shift of the current data ecosystem towards a more humane-by-design and autonomy-supportive future.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; • **Security and privacy → Social aspects of security and privacy**.

KEYWORDS

Datafication, Data Inference, Online Platforms, Children, Co-design

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1 INTRODUCTION

Today, children are spending more time online than ever before [63, 81]. Children’s data and actions are being pervasively recorded, tracked, aggregated, analysed, and exploited by online services, which can be used to manipulate their online behaviour, engagement, or content consumption [68, 72, 118], this contributes to the so-called datafied childhood [68]. On one hand, individual children and communities can benefit from big data, as data-driven apps, systems and platforms are starting to play a variety of roles in the digital ecosystems of children, enabling them to learn and have fun online [110]. On the other hand, data collection and analysis on a massive scale responds first and foremost to a business logic, labelled by Zuboff as ‘surveillance capitalism’ — *“a new form of information capitalism [which] aims to predict and modify human behavior as a means to produce revenue and market control”* [117]. At the core of this *datafication* is online services’ ability to make *data inference* on children, that is to analyse their data, supported by algorithms, with the aim to evaluate certain personal aspects relating to a natural person [68], in particular, to predict aspects concerning that natural person’s performance at work, economic situation, health, personal preferences, interests, reliability, behaviour, location or movements [5]. Such datafication is practically impossible to avoid or undo through deletion [63]. Furthermore, such activities take place mostly invisibly behind the scenes of apps and services and are less well understood or discussed as risks than other kinds of more easily characterised harms, such as the collection or profiling of particular kinds of sensitive data. Given that most adults have little understanding of how their own data are being collected, processed, and used to shape their digital environments [25], it is not particularly surprising that children too lack a robust understanding or adequate mental models of how their data are processed or used [58, 116]. On the other hand, a recent study on children’s perceptions of the datafication practices online showed that while there are still key knowledge gaps in children’s understanding of datafication practices, most children already possess rudimentary conceptual understandings of some aspects of datafication, notably those that they care most significantly about, and have a significant interest and willingness to take action to shape it to their desires [109]. This paper aims to extend existing understandings and examine how children would like to be supported in order to take action on the datafication practices. More specifically, we aim to explore two research questions:

- RQ1: *How do children currently perceive datafication and envision themselves to be supported?*
- RQ2: *What kind of designs are desired and needed by children to help them navigate datafication?*

To this end, we chose to use the YouTube platform as an example datafication platform [69, 76] for our study, due to its popularity among children throughout the world [9]. We used a series of co-design activities with children, including *fictional inquiry* [51] to help us explore children's perception of datafication and their requirements for support, and *feature redesign*, drawing on the framing from critical algorithmic literacy [30, 53], to help us explore the design mechanisms required and desired by children. We report our results based on 10 co-design sessions with 53 children, aged 7–14, from UK schools undertaken between May and June 2022. Our findings identified different types of envisioned support and design mechanisms desired by children of diverse age groups. This paper provides crucial insights for creating age-appropriate support for children's algorithmic literacy development, highlighted and unpacked the importance of no one-size-fitting-all designs when supporting children's coping with datafication. While previous research [14, 21, 64, 86, 101, 116] has looked at how children perceive data and their privacy online, our work extends this landscape by specifically looking at how children perceive issues around datafication – a phenomena that goes beyond basic data collection and related privacy issues, but refers to the entire pipeline in today's datafied society in which children's data are not only being collected, shared, but more importantly, algorithmically processed, analysed and exploited in ways that online services were able to make *inference* on them relating to personal aspects, leading to behavioural engineering and monetisation. We contribute a first understanding of how children aged 7–14 would like to be supported with datafication and what future data-driven digital experiences should be like for them, who demand a shift of the current data ecosystem towards a more humane-by-design and autonomy-supportive future.

2 BACKGROUND

2.1 Datafication on Online Platforms

To establish the scope of our investigation, we first aim to define what we mean by *datafication* online, which refers to the process that children's actions are pervasively recorded, tracked, aggregated, analysed, and exploited by online services in multiple ways that include behavioural engineering, and monetisation [68, 72, 118]. At the core of this *datafication* is online services' ability to make *data inference* on children, that is to analyse their data, supported by algorithms, with the aim to evaluate certain personal aspects relating to a natural person [64], in particular, to predict aspects concerning that natural person's performance at work, economic situation, health, personal preferences, interests, reliability, behaviour, location or movements [6]. By making inferences about individual's lives, datafication has been proved useful in terms of providing users with the services they want, therefore improving their online experience [15, 56]; but on the other hand, datafication has also been seen as a violation of privacy [25], and even as a potential threat to human autonomy [107] brought by increasingly sophisticated dataveillance techniques [93].

Meanwhile, datafication practices are becoming increasingly common in the online world today, and in fact, can be found on almost any online platform [26, 54, 89]. Existing research [89] found that big online platforms including Google and Yahoo have been using users' demographic data, data on interests and attitudes to make inferences about individuals or groups, which includes predictions about their future actions and inactions, general characteristics and specific preferences. Facebook has been found to make inferences on its users to form an 'interested reading' of their digital trace data [91], so as to create interest classifications that produce sales for advertisers and maintain user engagement on the news feed [104]. Research on Instagram also showed that there have been profiling practices on its users, to nudge them towards certain content such as idealised images which could have negative impacts on the body satisfaction of young girls [84]. Similarly, there has been evidence on YouTube conducting inference on users to maximise their engagement on the platform, which could be particularly problematic for the minors [84]. While various regulations have attempted to protect children from such practices, such as GDPR [28] for restricting profiling on children, and COPPA [1] for protecting online collection of personal information of children under 13 years of age, resulting in most social media platforms setting an 13/14 minimum age requirement for users to have accounts. In recent years, many has argued that this age limit has become more of an excuse for the social media platforms to continue to ignore the vast amount of under-aged children on their platform (whether using visitor mode, their parents' or siblings' accounts, or simply lying about their ages) [80, 83]. There has been clear evidence that children under 13s are still on, and even have heavy usage on social media platforms [80, 103]. A recent report on 2,002 US children showed that 45% of kids under 13 are on Facebook, and 40% already use Instagram [103]. While YouTube had a 'YouTube Kids' version that was claimed to be for under 13s, most children are still on the main platform and it remains to be the most popular video-sharing-platform among 8-12 year-olds, according to 2021 Ofcom report on UK children, with more than 85% of preschoolers found to commonly used YouTube to watch content [80].

2.2 Children's Perception of Datafication Online

There has been growing concern expressed relating to the datafication of children, especially as children may lack the awareness, knowledge, or mental faculties to be able to understand or be aware of such practices. Most previous research on children and data was around how children perceive their data privacy online, and mostly oriented around their understanding on how their personal information is collected online. While this does not equal to datafication, as the latter refers to practices beyond data collection, and extends to online services' ability to process the collected data and make algorithmic data inference on users for behavioural engineering and monetisation; however, these existing research on children's perception of online privacy provided us with a useful starting point as discusses in the following. A study with children aged 6-10 showed that while they could identify and articulate certain privacy risks well, such as information oversharing or revealing real identities online, they had less awareness of other risks, such

as online tracking or personalised promotions [116]. Similarly, a report on 169 UK children aged 11–16 showed that children primarily conceptualised data in relation to interpersonal contexts, but had misapprehensions about how personal data was collected, inferred and used by organisations and public institutions, such as their schools, or private/commercial businesses [101]. These findings were compatible with findings from a study in 2017 [86], in which teenagers aged 14 to 18 were found to have more concerns over interpersonal contexts, but often failed to understand or perceive potential threats to their privacy from ways first and third parties might make use of their data, and how personal data could be used in predictive ways to shape their future experiences and behaviors. In addition to children's limited ability to recognise beyond interpersonal privacy risks, children have been found to particularly struggle to draw personal connections to 'data traces' they left online [14]. Children showed limited knowledge about data flows and cross-platform data sharing, and as a result struggled to to view data flows as a dynamic process and imagine the wide impact on their personal privacy [21]. This was also identified by another study with children of different age groups, which found that children struggled to grasp the relation between privacy and data, and they would only focus on data they know they give, much more than data that is taken or inferred [64].

While children would likely have difficulties in fully understanding the complexities of datafication or its means, some more recent research has shown that children could be well-equipped and capable of grasping essential concepts related to datafication, for example, how their personal data (such as activity history) could be processed and used to sell products to the users (such as themselves). Studies have shown that if children were given sufficient scaffolding and nudges from parents and educators, their understanding could grow with experience [64]. A recent study offered a clearer picture on how children under 13 perceive and understand the datafication phenomena online [109], suggesting that they could already articulate the datafication practices quite well, demonstrating their rudimentary conceptual understanding (online datafication practices would "make guesses on them"), although not necessarily comprehending the full picture (such as how data could be transmitted across platforms and the subsequent cross-platform profiling). The study also identified significant willingness from children to take action to shape the online datafication practices online, especially in terms of having greater transparency and means of control on these practices. Inspired by these previous research, this paper aims to extend existing understandings and examine how children would like to be supported in order to take action on the datafication practices.

2.3 Datafication and Stages of Cognitive and Social Development

Children's ability to recognise and understand datafication practices may be influenced and limited by their particular stages of development, like many other kinds of cognition. For children aged 3 to 5, for instance, most online activities are still parent-guided, for instance, using apps and watching videos on parents' phones [81]. For children aged 6 to 9, they start to learn about the complexity of social relationships, and can start to feel various social pressures, such as the need to conform or desire to fit in with various social groups [80]. Children in this age group are also more involved in online activities, and enjoy playing games with their friends [46]. Such social interactions makes them more aware of interpersonal privacy risks, such as how their personal information being shared with their peers, parents, and others online [64]; but less of other privacy risks such as how first and third parties might make use of their data to shape their future experiences [64, 116]. At ages 10 to 15, many children start to become more active on social media [81]. At this stage, children's became more aware of how vloggers may be paid to endorse products or services [82], as well as online platforms may be monetising their data online [81].

Related to this recognition of how children of different stages of development are affected by datafication practices, there have been a variety of developments looking into how to support children developing their 'digital literacy' [29, 44, 52] as well as AI literacy [35, 37, 65]. However, such frameworks were often oriented around data privacy or online safety, with the algorithmic processing of data by online systems scarcely mentioned. On the other hand, 'critical algorithmic literacy' (CAL) [30, 53] puts particular emphasis on *understanding the implications of data processing*, by directing children's attention towards data and the algorithmic processes applied to them. The goal of CAL is not merely assisting the development of knowledge about algorithms but also an ability to engage in critique of algorithmic systems reflexively. The CAL framing proposed that computational thinking should include three key frames: the cognitive, the situated, and the critical thinking [53]. *Cognitive thinking* focuses on the understanding of key computational concepts, practices, and perspectives and the associated skill building and competencies; *situated thinking* encourages learning to take place in contexts that the learner cares about so that they include their personal expression and social engagement in their pathway of learning; and finally *critical computational thinking* recognizes that computing is not an unequivocal social good, and emphasises the importance of supporting the questioning of larger structures and processes behind the computational phenomenon. While there is no consensus on the best framework to use for supporting children's digital literacy development, and we do not claim the CAL framing to be the best approach for scaffolding children's knowledge about datafication, in this paper, we introduced elements of the CAL framing into our co-design activities, as a way to invoke children's discussions and identify the more nuanced and in-depth design needs of children.

2.4 Co-designing with Children

Co-designing with users has been an increasingly popular design method over the past few decades [100]. Having roots in both US-driven user-centred design approach [41] (i.e. "user as subject") and the Scandinavian participatory design approach [79] (i.e. "user as partner"), co-design can comprise diverse approaches, ranging from research-oriented ones (e.g., applied ethnography) [99], to design-oriented ones (e.g., using generative tools) [27]; and ranging from approaches in which researchers and designers move toward users (e.g., usability testing) [62], to approaches in which users move toward researchers and designers (e.g., participatory design) [100]. The term *co-design* is defined by Sanders and Stappers [92] as "the

act of applying the collective creativity of designers and people not previously trained in design who work together across the whole span of a design process", and by Kleinsmann and Valkenburg [57] as "actors from different disciplines share their knowledge about both the design process and the design content in order to create shared understanding" – emphasising co-design as processes of creative cooperation and developing shared understanding. In the last decade, the Child-Computer Interaction community has been actively adopting co-design methods, and increasingly value the direct involvement of children in the design process [38, 61, 112]. Druin developed a widely adopted model for involving children in the design process – children can take on various roles, including users, testers, informants, and full design partners [40]. The first two roles focus primarily on obtaining feedback or input from children at the end of the design cycle; the latter two focus on idea elaboration, where children as *co-design partners* are positioned as *equal* design partners with adult co-design partners, and are expected to be equal stakeholders in the design of new technologies and have an equal opportunity to contribute to the design process [40].

In our work, we conducted co-design sessions with children, during which children are considered to be equal stakeholders [40]. This was a critical design decision so that we can not only boost the chance of developing viable and usable designs for children [98] but also support the empowerment of children in shaping the direction of innovating technologies and concepts [71]. We specifically focused on working with children as *co-design partners* using the method of Cooperative Inquiry (CI) [39, 40]. First proposed by Druin [39], CI emphasises the close partnerships with children, during which children are considered designer partners who hold expertise in being a child [49]. The method has been widely adopted in various previous studies, and proved to be effective especially in terms of investigating the existing conceptualisation of children on digital phenomenon/artefacts, and eliciting the design needs of children. Previous scenarios include designing with children for intelligent interfaces [113], social robots [16, 36], online safety applications [59, 70], remote technology use during pandemic [18, 74] as well as AI literacy framework for families [38]. Meanwhile, researchers have used a range of techniques to communicate and co-design with children. Walsh et al. [108] created a framework to help researchers select, create, and modify design techniques based on the context of design. For instance, techniques such as Fictional Inquiry [34, 51], Big Papers [48, 108], and Bags-of-Stuff [49, 114] are more typically used at the early stages of the design process for eliciting children's perception of a topic; and techniques such as Comicboarding [51, 77] and Stickies [114, 115] are more generally used in later stages for evaluation.

3 METHODS

Given our focus on investigating how children want to manage datafication practices online, we chose the YouTube platform to be used as an example, and conducted a series of co-design activities with children, including fictional inquiry and feature redesign, to elicit their requirements. We selected YouTube as the exemplar datafication platform because it contains a variety of data processing practices, and is familiar by most children [46, 82].

3.1 Study Design

To encourage children's involvement and their voices in the co-design process, we planned each co-design session to be composed of 3 activities: 1). Pre-design activity, 2). Co-design activity #1: Fictional Inquiry, and 3). Co-design activity #2: "Big Paper" Feature Redesign . The fictional inquiry session was designed to be more open-ended and to collect children's perceptions and how they envision to cope with the datafication practices; while the feature redesign session was more scaffolded by drawing on the CAL framing (see Section 2.3), in order to allow us to identify the actual support/design mechanisms needed by children to manage datafication. Each session was designed to last about 1.5 hour, consisting of 5–6 children and 2 adult researchers as co-design partners. The co-design groups were then broken into two design teams for Co-design activity #1 (*Fictional Inquiry*) and #2 (*"Big Paper" Feature Redesign*), with each design team containing 2–3 children and one adult design partner. In each design activity, the adult design researchers acted as partners by designing with children and facilitating discussions. After each design activity, the two design teams came back together for discussion. Throughout the study, adult partners co-designed with children and facilitated discussion in a way that avoids influencing the direction of the design and carried out conversations by encouraging children to clarify their design intents, rather that trying to guide the direction of discussion.

Pre-design Activity. The warm-up session included a game of "throwing a ball" [78] and invited everyone in the room to share their favourite YouTube video with others. This session was designed as a break-the-ice session to help the children to relax and get familiar with each other and the researchers. Then children were asked about two questions: *How do you think your video recommendations are generated? How do you think your personalised advertisements are generated?* We followed up children's responses by asking them to explain any terms they mentioned, such as "cookies", "trackers", or "profile". We have not intended to introduce this activity for learning purposes. The adult researchers did not try to provide children with a "right" answer, or provide guidance to elicit responses to those questions in any way. Instead, children were encouraged to express their own perceptions and opinions about datafication and related issues without being judged as right or wrong. These questions were designed to give us an initial insight about children's understanding of the datafication practices online. Particularly, we invited children to talk about their perceptions of datafication practices taking place, and their understanding of data inferences and profiling.

Co-design Activity #1: Fictional Inquiry. In co-design activity 1, we conducted a fictional inquiry session. Fictional inquiry is a participatory design technique that entails creating an immersive fictional storyline and prompting participants to brainstorm within the context of this imagined reality [51]. By creating a fictional context for individuals to develop ideas, this method attempts to reduce the constraints of reality and free participants to be more generative. Prior work has showed this technique to be effective with children as young as 5 for eliciting their requirements [33, 51].

In our work, fictional inquiry was used for facilitating children to think about their experiences with datafication practices, as well as how they may want these experiences to be different/better. For this, we created an original story titled "Noah and Lola: and a

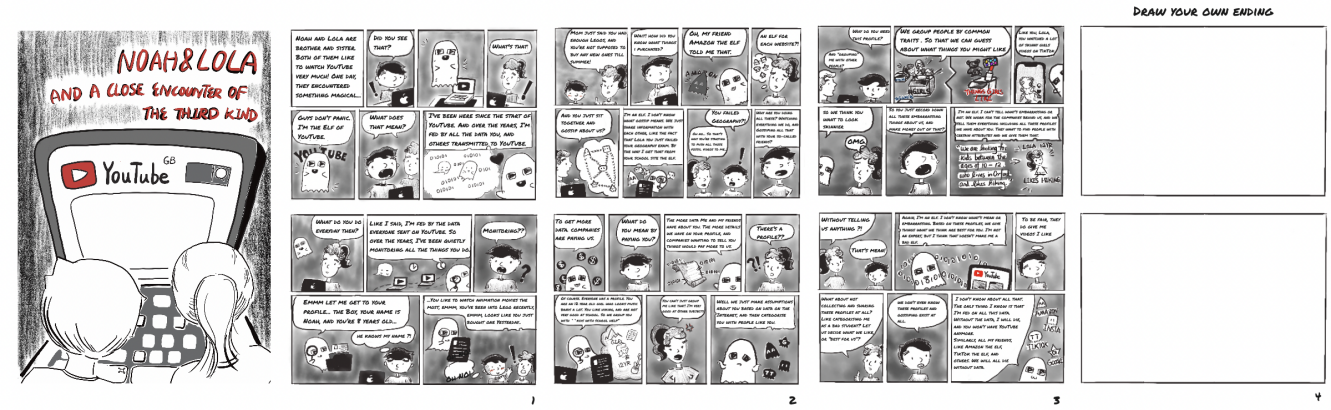

Figure 1: Fictional storyline used in co-design activity #1 for children to read through and complete as a group.

close encounter of the third kind" (Figure 1). The story describes Noah and Lola, who are brother and sister, meeting the YouTube elf (representing the YouTube platform) one day and having to decide what to do with the elf. In the story, the datafication practices were described to children through conversations between the three main characters, and the story was left open-ended. During the design, we made a careful choice of our character (use of "elf" instead of characters that were typically perceived more negatively such as "monsters" or "witches" [17, 50]) to avoid introducing any negative affections to the practice of datafication and tried to remain as neutral as possible by explaining both the good side and down side of datafication in the story.

At the start of this session, all children and adult design partners were invited to role-play when they read aloud the story as a group: each design partner took the part of a character from the story, and read out its lines. We noticed that this helped children to become more engaged and pay more attention to the story. After finishing reading the story, the adult design partners encouraged the group to discuss on "*What happened in the story?*" This helped the adult design partners to confirm what children understood about the story, and facilitate discussions to clarify the story if needed. The group was then split into two design teams (each with 2–3 children and one adult) to draw their suggestions about what Noah and Lola should do with the YouTube elf. After working on this task for 30 minutes, the design teams came together and each team presented their stories in front of the whole group, while an adult design partner took notes. The adult design partners then synthesized story ideas across the group and facilitated group discussions based on these ideas. During the design process, design partners were explicitly reminded not to focus on how well they can draw, but what goes into their story. We have not intended to design or introduce the fictional storyline for education or learning purposes due to the relatively short duration of the study; instead, this activity mainly aimed to invoke children's discussions about datafication and their envisioning on how to cope with these practices.

Co-design Activity #2: "Big Paper" Feature Redesign. In the co-design activity 2, we drew on the aforementioned CAL framing (see Section 2.3) and presented children participants with a collection of design mockups (see Figure 2) in order to identify how children may perceive these designs that are built upon different levels of computational thinking, and thus provide different levels of transparency and degree of controls. Children were presented with mockups of changes to two key mechanisms on the YouTube platform—video recommendations on the homepage, and personalised advertisements that show up at the beginning of a video. These two mechanisms were chosen as they were considered to be the most representative for the datafication practices on YouTube. For each of the two mechanisms, we created 3 mockups for transparency, and 3 mockups for control, varied with the 3 design thinkings from CAL. As was discussed in Section 2.3, the CAL framing proposed that supporting the development of computational thinking should include three key frames: the *cognitive*, the *situated*, and the *critical* thinking:

- The **cognitive-thinking** version of *transparency* mockups (the left card in Fig 2) provides the basic information, such as category of data being collected and used to generate video recommendations/personalised ads, without going into the details and the implications; and the *control* mockups were designed to offer a basic control on these different categories of data. (e.g., *We choose this ads for you based on: the time of day or your general location, your age and gender, your interaction with similar ads, and our estimation of your interests.*)
- The **situated-thinking** version of *transparency* (the middle card in Fig 2) and *control* not only display the data being collected and used for video recommendations/personalised ads, but also provide a contextualised explanation and control option according to children's personal experience on YouTube and multiple other online platforms. For example, in addition to the YouTube videos children watched, the design mockup also shows children the websites they visited and the products they purchased on third-party platforms. (e.g., *We choose this ads [Worms Rumble - Launch Trailer | PS5, PS4] for you because: you searched for "Worms Rumble" 8 times last week on Google, you purchased a PS4 console this week on Amazon...[other online activities].*)

- Finally, in the **critical-thinking** version of *transparency* (the right card in Fig 2) and *control*, we tried to reveal the bigger picture behind video recommendation and personalised ads, explaining the process of profiling and offerring controls on this profiling process. (e.g., *We collect all your activities across all websites you visited into a profile, that means all your digital footprints on the Internet. Your profile is as follows: Love gaming, particularly into Worms Rumble (information from YouTube and Steams)... [other interests assumptions].*)

The 12 mockups and the detailed explanations on the exact features can be found in Figure 4 and 5 in Appendix.

Again, in each session, 5-6 children and 2 adult researchers participated as co-design partners. The adult partner first presented the group with the CAL-inspired mockups on a big screen. Each child partner spent five minutes reviewing the CAL-inspired mockups, which were showcased on the screen in a random order. Each child partner was then invited to go through what they like and don't like about each of the mockups in front of the group. The co-design group was then broken into two design teams (each with 2-3 children and one adult), to think about how they would like to redesign the given mockups. Each team received a packet of printouts of the mockups, pens and pencils, scissors, markers, and tape. We used the "Big Paper" paper-prototyping technique [48], where design partners directly iterate upon previous designs by cutting out, drawing upon, and marking up printouts with their suggestions, additions, and changes [49]. After working on this task for 40 minutes, the design teams came together and each team presented their ideas in front of the whole group while an adult design partner took notes. The adult design partners then synthesised design ideas across the group and clarified and elaborated these ideas through discussions with the children. In our study, the CAL-inspired mockups were used for facilitating children's discussion and brainstorming on their needs when dealing with datafication practices; and whether such needs would have any age-appropriate implications. We do not claim that CAL is the best approach for scaffolding children's knowledge about datafication; however, we introduced elements of it into our mockup designs as a way to invoke discussion and the more nuanced needs of children.

3.2 Participants

Participants were recruited from local schools, and a public forum for recruiting family participants. Recruitment started in May 2022 after obtaining institutional research ethics approval, and we conducted 10 co-design sessions (with an average group size of 5) with 53 children between May and June 2022, contributing towards a total of 19 co-design teams made up of children and adult design partners. We made a careful selection on the age range of the children participants, setting it as from 7 to 14. We chose to work with this age group for several reasons: previous research has shown that from 7 onward, children started to become more heavily involved in online activities especially social media [81], and gradually transitioned away from mainly parent-guided online activities [80]. Meanwhile, as was explained in Section 2.1, children under 13 are active users on many social media platforms despite of the age restrictions claimed by these platforms [83, 90]. There is also clear evidence that, not only children below this age threshold are heavy adopters of online social media, but they already demonstrate some rudimentary conceptual understanding of online datafication (see Section 2.1). This age group is also consistent with previous work on CI [19, 48, 73, 87, 106], demonstrating their competency in participating co-design activities [64, 109]. Among the 53 participant children, 25 were between 7 to 11 [1], another 28 were among the age range of 12 to 14 [2], with an average age of 11 (range = 7–14, s.d. = 2.05).

Apart from the age of participant children, we also made a careful selection ensuring the diversity of the demographic background of our participants. Children were recruited from five local schools: two private schools [3], one grammar school [4], and two state schools [5]. For the participants recruited from public forums, we also noted down the type of schools they attend, participants' demographic information including their ethnicity, YouTube usage behaviours, and some basic information on their schools' and family education on topics related to datafication (see Table 1 – 3 in Appendix for summary and details on individual participant).

While participants were recruited from schools and public forums, the co-design sessions were not conducted in a school setting to mitigate the potential influence brought by the typical power structure in a school setting in which adults such as teachers exercise authority over children [106]. Instead, children signed up to our study were invited to our lab. This also allowed us to carefully organise children into groups, so as to ensure that single-session participants were of diverse ages, genders, ethnicity groups, types of schools attended, and related experiences on datafiation. Meanwhile, we tried to maintain an equal partnership between children and adults throughout all session. For example, sessions often begin with a snack and casual conversation; participants wear informal clothing; and children do not need to raise their hands to speak nor refer to adults by their titles or last name. Extra attention was paid to children who were younger, or knew less about the subject, or simply being shy.

3.3 Data Analysis

After completing the ten design sessions, the first and second authors transcribed all the video recordings. There was a total of 927 minutes of video data (not including snack time at the beginning of each session), which resulted in a total of 1853 utterances used for analysis. Out of the 1853 utterances, 1396 were made by children (75.3%), the rest were made by adult design partners (researchers). We analysed the data using a grounded, thematic approach [22] to develop codes and themes related to each of the three parts of the study. Photographs of children's drawing were also consulted to complement our analysis.

The thematic coding process started by dividing the transcriptions into two equal-sized sets. The first two authors independently analysed the first set of transcriptions to derive an initial set of

[1] Primary school age in the UK.
[2] Secondary school age in the UK.
[3] Private schools (also known as 'independent schools') in the UK: charge fees to attend instead of being funded by the government.
[4] Grammar schools in the UK: government-funded schools that are allowed to select their pupils by means of an examination taken.
[5] State schools in the UK: government-funded schools that provide education free of charge.

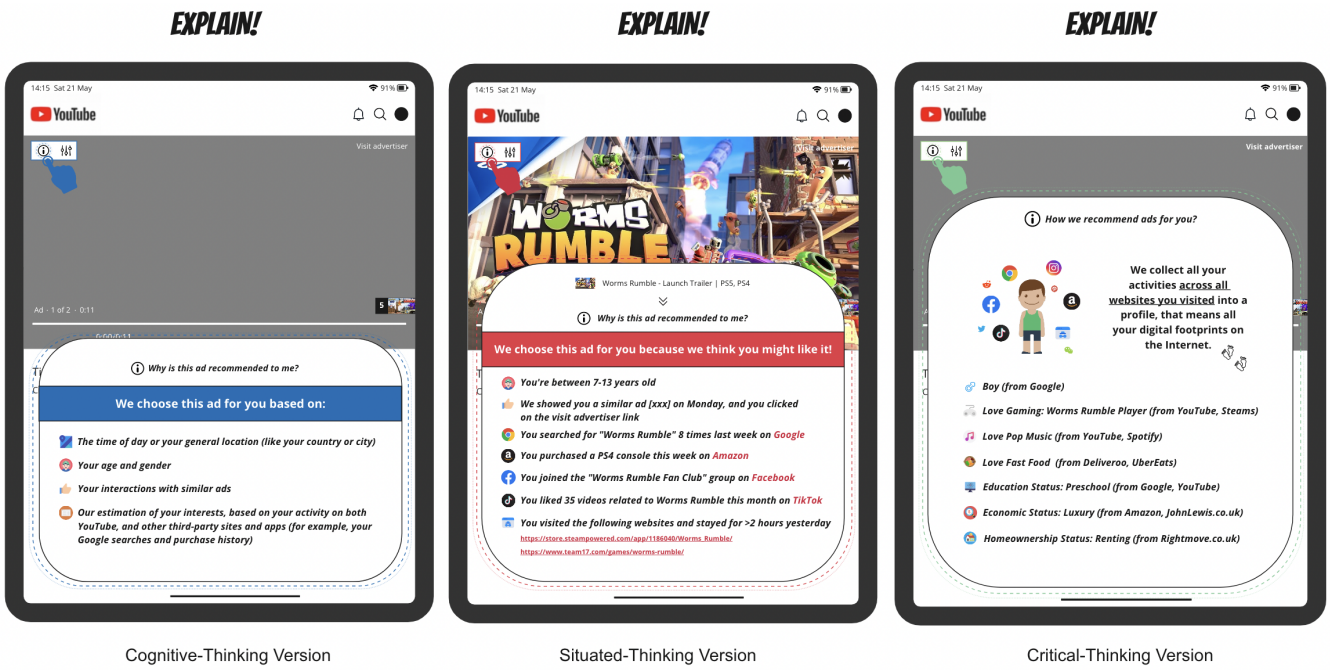

Figure 2: Transparency mockups redesigning the personalised ads mechanism on YouTube (EXPLAIN! cards). We created three versions of the mockups drawing on the CAL framing: cognitive, situated, critical. Each mockup was evaluated and later redesigned by the participants in the co-design activity. For more details on all 12 mockups, please see Figure 4 and 5 in Appendix.

codes (for each of the three parts of the study). They then met to consolidate and reconciled codes into three common codebooks for each part of the study, with Cohen's kappas of 0.79, 0.78, and 0.78. More specifically, results from part 1 of the study (Pre-design Activity) contained children's understanding of the datafication practices online. During the coding process, we tried to calibrate how children understand the YouTube's data processing practices, and this led towards a codebook on children's understanding of the datafication practices. Results from part 2 of the study (Co-design Activity #1: Fictional Inquiry) contained children's brainstorming on their designed story endings for the fictional storyline. Our analysis identified how children currently perceive datafication and their envisioning on how datafication should be dealt with. This led towards to a codebook on children's conceptual model on how the current datafication could be dealt with, what went wrong and what could be done better. With respect to the data collected from part 3 of the study (Co-design Activity #2: Feature Redesign). We first categorised children's rankings and comments around the three sets of CAL-inspired mockups (cognitive, situated and critical) for both transparency and control (EXPLAIN! cards and CONTROL! cards). For children's proposed redesigns of the mockups, we clustered their proposed design mechanisms. This gave us a codebook on the specific design mechanisms/support children want to have for knowing about and controlling the datafication practices.

4 RESULTS

We present our results by first outlining children's overall understanding of the datafication practices online. We then present children's perceptions of datafication and their envisioning on how to cope with datafication. Finally, we present our analysis on children's preferences of the CAL-inspired features, followed by an in-depth analysis regarding children's desired design mechanisms for coping with datafication, with specific examples from our design sessions (e.g., [DSx]). We present individual children's quotes with their participant id and age. For information on our participants' demographic information, please see Table 1 – 3 in Appendix.

4.1 Children's General Understanding on Datafication Online

In general, we noticed that children's understanding of datafication aligns with their age group, and can be broadly categorised into three phases (7-9Yr, 9+ to 11Yr, 11+Yr). This categorisation is also found to be aligned with UK ICO's Guidance on Age and developmental Stages [4]. In the UK, age 11 is also an important transition year for children to enter secondary schools. Here we report their understanding of datafication clustered into three major themes: *data collection, data sharing*, and *data inference*.

Starting with children between 7-9Yr, children in this age group largely demonstrated an awareness of the *data collection* practices on YouTube, especially how their recommended content could be generated based on their activities on YouTube (e.g., videos watched,

Age Group	Datafication as *Data Collection*	Datafication as *Data Sharing*	Datafication as *Data Inference*
7 to 9Yr	Data on my interactions with YouTube (videos watched, terms searched, likes and comments) is collected to generate videos for me **These data are not owned by me, and they are not my personal information**	Collected data will be stored by YouTube, may be shared across departments within YouTube **Data won't be shared (traded) across platforms**	Some basic conceptual knowledge on collected data could be used to *do things,* but can't articulate more **Not aware that data could be used to infer personal aspects of them**
9+ to 11Yr	Not only what I do on YouTube, but things I do on other platforms would be collected to generate recommendations **Not sure data on which platforms would be collected (tend to think within Google)**	Collected data will be shared across platforms **Data will only be shared across platforms that are related (e.g., under the same company, visited through the same browser)**	Data is processed through algorithm/some kind of automatic process, through which guesses about me (e.g., what I might like) could be inferred **Find it hard to understand how "guesses about me" could mean for other aspects in their life apart from "giving me better videos"**
11+Yr	Data collection is enabled through *Cookies* There are terms and conditions on data collection in user agreement **Can't really describe how exactly is data collection enabled (apart from knowing the term *Cookies*)**	*Trackers* are used to track my activities across platforms **Can't really describe how exactly is data sharing enabled (apart from knowing the term *Trackers*), only vague ideas on data might be traded, but don't know how**	Data inference is making *profiles* about people **Can't describe how exactly is inference conducted** **Think they have rights, but don't know how to implement those in a datafied society**

Figure 3: Summary of children's understanding of datafication, organised into three themes.

terms searched, location information). Meanwhile, most of them only considered location information as personal information and think the platforms own this data; instead, they do not think their online activities data such as videos watched and terms searched are personal information, and many (7/11) regarded these data as "*owned by YouTube, not by me*" (P5, age 7). Meanwhile, children in this age group generally did not have much idea on the *data sharing* of their data, especially how it could be shared across platforms. None of them thought data would be shared, or traded by YouTube to another platform/company, as *"Why would they do that, I thought they [YouTube, TikTok] are enemies."* (P11, age 7). As a result, they tend to think data would only flow within *"different departments of YouTube"* (P12, age 8). In terms of *data inference*, most children in this group were not aware that once their data is collected, it could be used to infer more sensitive things about them. This point was also reflected in the later on co-design sessions, in which many of them demonstrated confusion on how profiles about users could be set up.

Children between 9+ to 11Yr all demonstrated an awareness of the *data collection* practices on YouTube, and how their recommended content could be generated based on not only what they do on YouTube, but also their activities across multiple platforms *"If you visit a coffee website, YouTube will give you ads on coffee."* (P19, age 10). While some children (8/13) were able to discuss how data could be transmitted across platforms, they demonstrated different understandings in terms of how such across-platform *data sharing* is enabled. Many of them (10/13) thought data sharing was only performed between YouTube and websites that they visited through Google Chrome, as *"YouTube and Google is the same company."* (P40, age 11). As a result, they generally thought they won't be tracked as long as they don't sign in to a Google account, or just use other browsers such as Safari and Firefox. In terms of *data inference*, most children (9/13) in this group had some awareness or had heard about this topic, describing data inference as *"make guesses about me"* (P46, age 10). Some of them also mentioned the concept of algorithms, such as how their recommendations is *"automated by algorithms"* (P29, age 11) or *"some kind of machine"* (P24, age 10). Meanwhile, they were less certain about the specific things that could be inferred about them. For instance, while they described data inference as *"categorise people and influence the content they get"* (P17, age 11), they generally believed such inference was only for better videos per se, and found it hard to connect to other aspects in their life.

For children aged 11Yr onward, they tend to have more understanding on topics around datafication. Unlike the younger age groups who sometimes have some understanding on a certain topic but cannot describe fully, many children in this age group can accurately name specific terms in datafication, such as *data collection* is enabled through *cookies*, and cross-platform *data sharing* could be achieved through *trackers*. Meanwhile, some directly used the term *profiling* when referring to *data inference*. Children in this age group were more aware of the monetisation process behind scenes. For example, in conversations during design activities, many (19/28) mentioned that the companies are trying to make money – *"They collect our data because they want to sell it."* (P43, age 14); *"They all have some kind of partnership, for trading users' profiles."* (P45, age 14). On the other hand though, children were less certain when talked about how the datafication practices actually work *"I guess it's [enabled through] some kind of algorithm, but honestly don't know anything about it."* (P32, age 13). Furthermore, some of them (13/28) demonstrated confusion in terms of why platforms nowadays would try to infer/learn things about people, and were generally unsure about what rights do they (or can they) have in a datafied society.

4.2 Children's Envisioning on How to Cope with Datafication

In the part 2 of the study, children were guided to draw their own endings to the fictional storyline provided to them, making suggestions to the fictional siblings regarding what they should do with

the YouTube elf. This activity encouraged children to think about how they would perceive and cope with datafication. Although the drawings from the children provided some valuable indications of their requirements, we found the discussions and think-aloud during the process presented additional and richer insights.

4.2.1 Demand for more respect from platforms. One of the most reflected points from our children participants was how they generally felt that they could be more respected by the platforms, through more interactive communications and dialogue. As such, children proposed three possible directions:

Increased Transparency. Many children expressed that more transparency about how platforms function and what they do with their data would be critical for them. Particularly, they often referred to the lack of transparency in the current terms and conditions provided by the websites, as a direct example of how their trusts of platforms are affected: *"Literally anything could be in the terms and conditions, if you're willing to sell your soul or something, but nobody would pay attention."* (P35, age 11). Some children also brought up the more design-level lack of transparency, such as how they identified the *"sneaky"* (P17, age 11) design patterns could hinder their autonomy online, and nudge them towards unwise decisions: *"If you click no (to the cookies) they say the app won't function, like a bunch of negative things."* (P16, age 10). Many children argued that they think it is important for platforms to make more child-specific considerations. Some children mentioned how they would want a child-friendly version of the terms and conditions, which can *"actually help me know what's going on"* (P41, age 12); while children suggested that they would like to be especially reminded of the *"important matters"*, such as *"profiling and selling of info - that's what most people actually care about"* (P39, age 9).

Increased Control. Children also brought up how they think platforms could be more respectful by providing users with more power of control: *"Yes being able to see things is nice, but what's important is that we would actually be able to do something about it."* (P27, age 14) Starting with data collection, children talked about how they would like to control the *"types of data being tracked online"* (P18, age 9) as well as the *"types of data being traded online"* (P20, age 11). Some children also mentioned how they want platforms to minimise the datafication practices: *"limit the data they harvest to only what's needed"* (P36, age 8), and *"delete our profile after an amount of time"* (P24, age 10). Furthermore, many children talked about how they want to be able to control their profiles. In particular, some children brought up the idea of having *"privacy-preserving profiling"* options, and they brainstormed on ways such as anonymising or randomising all profiles so that "platforms won't know as much about my life" (P28, age 11). Meanwhile, children also mentioned how they want to be supported when making decisions, and how they expect the platforms to guide them throughout this process: *"That's something the elf should be helping us with — making good decisions"* (P15, age 13).

Increased Sympathy. Related to develop communication and interactions with platforms, a strong theme is that children want to build a relationship with the platforms. Many children, especially the younger ones, described how they want to have *"actual bonding with the elves"* (P11, age 7), and building *"friendship with the platform"* (P23, age 9). In particular, they used words such as *"thinking for me"* (P22, age 14), *"be considerate"* (P46, age 10). A group of children [DS5] envisioned a scenario in which they can tell their secret (which is their data and profiles) to the elf, and the elf would help to protect that secret — *"the elf wouldn't tell anyone"* (P27, age 14). This idea echoed with the story from another group of children [DS3], in which they described a concept of a *"value-sensitive elf"* — instead of just being an algorithm which is programmed to do its job, the children want the elves to be actually taking caring of them and protecting them online: *"The elf can actually tell that, oh this information might be too sensitive or embarrassing for this child, so I won't hurt them."* (P7, age 12).

4.2.2 Demand for unbiased digital experiences. How datafication may influence their experience online was extensively discussed by the children during the fictional inquiry session, ranging from bias and discrimination, to targeted promotions, and to filter bubbles. To start with, some children discussed how they think the current datafication practices could create bias and discrimination due to them trying to *"group people online"* (P19, age 10), and how bias could arise due to *"gender steoreotypes"* (P33, age 14) or *"how rich they think you are"* (P17, age 11). In terms of how to cope with this, children argued that it is the platforms' responsibility to avoid bias and discrimination and they proposed a *"scrutinising algorithm"* that platforms could develop to assess whether bias and discrimination exist, and that algorithms used for profiling should not be based on sensitive categories: *"when they are profiling on people, they should know there are things people don't want you to profile."* (P36, age 8). Meanwhile, children argued that advertisers shouldn't be marketing on people based on sensitive categories from the beginning: *"It's 2022, and you're still targeting boys v.s. girls, you will get cancelled."* (P41, age 12); *"Ban advertisers from using some parameters for their ads, so now they can't ask YouTube to target certain groups."* (P18, age 9) Apart from bias and discrimination, some children also argued about how datafication could lead to echo chambers online: *"The profile would restrict the things you see, pushing you to whichever group they think you're in."* (P9, age 11); *"so people don't have a full view"* (P33, age 14) Children brainstormed on new mechanisms to increase their content diversity, a group of children [DS6] introduced an *"explorer mode"* in which users would be given more freedom to see what's outside their world — *"Like I'm a boy living in the UK and speaks English. I would want to see what a girl, say living in India would see."* (P29, age 11). Many children also mentioned how they want to more directly see whether they are in an echo chamber — how their content were limited by the profiling of them, for example, *"we recommend this to you because you are tagged with this"* (P12, age 8).

4.2.3 Demand for fundamental changes made to the datafied society. An interesting theme emerged from children's discussion is that, many of them believed that datafication is becoming a social issue, and they talked about how stakeholders - platforms, users, regulators should take an active role in the increasingly datafied society. Such belief has been even transformed into some kind of *data activism* — *"fundamental changes need to be made"* (P42, age 13).

Increased Public Awareness. Many children talked about how the datafication phenomena and associated consequences should be made aware by the public. They felt currently such practices were

largely unknown by the general public, and they talked about how *"social movement"* (P5, age 7) and *"campaigns on social media"* (P4, age 8) should be brought in thus to *"spread the world"*. A group of children [DS2] even brainstormed on organising public protest on the datafication phenomena and its related issues: *"Noah and Lola would make a website, and ask people to join their protest."* (P6, age 12). Apart from relying on the public efforts, some children also talked about how they want new regulations to be made for protecting them against these datafication practices online, such as *"an upgraded version of GDPR"* (P42, age 13).

New Business Models for the Datafied Society. A large proportion of the children demonstrated a strong awareness that data is online platforms' main source of money. In fact, many of them have already accepted it as a norm that companies would be making money based on their data, in exchange of the services they offer: *"It's all about data selling, and it's very difficult to shut down something that is their core business."* (P8, age 14) On the other hand, some children envisioned there should be some kind of revolution on this data-centred business model. Children in our study generated several versions of *"new business models"*. For example, a 'Weight Loss Scheme" [DS6]: *"The Internet could go on a diet, like eating less but healthier - taking less but more effective data. And whoever signed up to it would be promoted more."* (P30, age 12) Another group of children [DS8] generated a similar idea to this — a "Fair Trade Union". Companies joining would be checked on the fair use of users' data, and thus get promoted more. A group of children [DS10] envisioned a *"Data Pass Scheme"*. The idea was that users would pay companies for them to stop taking their data (through purchasing "data blocks"). On the other hand, some children began to question why platforms have the rights to make money from their data in the first place: *"We should be the ones getting paid as it's our data."* (P41, age 12) and described such data-centred business model as *"the ultimate scam"* (P42, age 13). Finally, some children [DS5] talked about some initial ideas towards a data-decentralised structure - future platforms would only be passing requests from their local device: *"Every phone or laptop will have a creature living inside. But it only does things locally, like providing you service based on what's in your phone, but not giving your information away to YouTube or TikTok."* (P25, age 11) and platforms would *"only be parsing whatever is requested by these creatures."* (P24, age 10).

4.3 Children's Desired Designs Mechanism for Coping with Datafication

In the part 3 of the study, children were asked to comment and redesign the provided CAL-inspired mockups. We observed three themes about how children would like to be supported when coping with the datafication practices on YouTube. First, children demonstrated *age-related* design needs for them to make more informed choices. Second, children envisioned more *humane* designs that treat them in more respectful ways. Finally, children desired for more *autonomy-supportive* designs for more active engagement. Importantly, these proposed design mechanisms aligned closely with the themes emerged from their envisioning on how to cope with datafication during the fictional inquiry, demonstrating children's desire of transforming their conceptualisation to concrete design practices.

4.3.1 Age-Related Needs for More Informed Choices . Although the fictional inquiry sessions indicated some differences of responses from different age groups, our feature redesign activities led to more specific age-related observations. Children often showed different preferences and expressed different needs for how they want to be supported, often depending on how familiar they are with datafication concepts, which was typically related to their age.

Starting with children who had possibly less datafication knowledge (typically between 7–9Yr), almost all of them (10/11) preferred the *cognitive-thinking* designs the most, which present children with the basic information about what data was being collected and how. They found these designs *"easy to understand and configure"* (P36, age 8). Meanwhile, they largely disliked the *situated-thinking designs*, which listed their activities and showed how their recommendations were made based on these activities; and they reported feeling *"being judged"* (P49, age 9) and *"unsafe"* (P11, age 7). They also disliked the critical-thinking designs, considering the designs mentioning profiling as *"random"* (P4, age 8) and *"feels unreal"* (P5, age 7). Interestingly, even though these children were previously able to describe some basic datafication concepts such as how platforms take and make use of users' data; they seemed to have difficulty in relating such abstract concepts to their own datafication scenarios, thus showed understanding barriers and felt intimidated when actually being showed what datafication can learn about them. Children also exhibited desire for more straightforward and more direct support for coping with datafication. For example, P11 (age 7) suggested removing the "complex sentences", explaining: *"I feel like 'we build your profile' is a bit too deep"*, and just using words like *"We could guess what you like."* Children also wanted simpler control configurations and they especially liked the idea of having a *"one button for all"* (P12, age 8), proposing designs that can *"stop profiling in just one click."* (P5, age 7). Meanwhile, they preferred more direct and obvious support when making decisions. For example, they wanted for designs that *"just tell me what to do"*, giving them direct instructions on *"if clicking on this button is good or bad"* (P36, age 8), or direct parental help *"Mom will tell me what to do."* (P10, age 8).

We found that children (usually between 9+ to 11Yr) in our study started to demonstrate a different set of preferences, going through a transition phase. They showed more positive perceptions towards the situated-thinking designs for them being *"more related to me"* (P46, age 10), while some disliked the cognitive-thinking designs, for them being *"too vague"* (P16, age 10) in the explanation, and being *"too broad and general"* (P20, age 11) for exercising controls. These children were able to connect abstract datafication concepts to *me*, and care more about how *me* would be affected by the datafication practices. Such a contrast to the younger participants was also reflected in their design proposals, which included significantly more designs on managing things about *me*. For example, P16 (age 10) envisioned for designs to tell them more specifically how profiles were formed around *me*: *"How they made that guess. Maybe like put up a search history, saying that I have searched this on this day so they think I'm a child or a boy or something."* Children also showed greater interest in controlling things about *me*, such as *"removing these guesses about me on my profile"* (P25, age 11) and *"choosing which websites can receive my profile"* (P52, age 10). In general, children want to be able to decide what goes onto their profile, how

it's generated and could be used. In terms of how they want to be supported, it is interesting to see that, unlike younger children who preferred direct help, children from this age group wanted for support that help them make their own choices: *"Tell me the consequences of my choices, but let me decide."* (P35, age 11), and they expected parental involvement in more communicative ways instead of just telling them what to do: P17 (age 11) explaining *"We added a button here to invite parents to do these settings with us."*

Finally, from around 11Yr onward, children in our study largely found the cognitive-thinking insufficient and preferred the situated and critical-thinking support. Meanwhile, they demonstrated greater interest in the critical-thinking designs. Apart from *things about me*, children from this age group started to also become interested in *things about people other than me*, and more broadly around the datafication phenomena and its implications. This is also reflected in their designs, such that they started to want designs that explain *"the full picture of datafication"* (P38, age 14) to them, including topics ranging from algorithms used in the datafication practices — *"the kind of formula, weights of factors used in the algorithm"* (P34, age 13), to what are the *"data partnership between the websites I visit the most"* (P31, age 12). Children from this group not only care about *what* is being done by the datafication practices, but also *why* the datafication practices were performed and how it would have greater impact. They expect designs to be delivered in ways with both facts and reasoning behind the facts. When comparing to younger children, children in this age group demonstrated interest beyond *things about me*, and extend such interest to "people around me" and the greater society. For example, P45 (age 14) talked about wanting to learn *"how my data, my friends data, my parents data, and everyone's data is combined and merged by them [platforms] and how it [datafication] would have effect on every single one of us."*. P31 (age 12) also described: *"Why they [platforms] are doing all these, how it benefit them and how it may have impact on us as users, and maybe even how it would impact the society."*

4.3.2 Demand for More Autonomy-Supportive Designs. Children in our study envisioned several key designs to assist them to have greater autonomy, i.e., to take more *active roles* when coping with datafication practices, where the children felt like they should be the ones to initiate the action. To start with, some children proposed that it is important for them to receive alerts and notifications in a more visible way so that they could take an active action. For example, P11 (age 7) described the design of *"a huge question mark that you can click on, at every place they brought up this profiling thing. To me, that's more important than other things"*. Furthermore, many children expressed that it is crucial to have more simplified designs that encourage *active* actions, instead of having to navigate complicated user interfaces. As a step in this direction, P18 (age 9) sketched a home screen that present users with all the settings they can configure on one page, instead of *"hiding all settings under sixteen layers of pages"*. Some more active designs include the ones that enable children to inspect on things to ask for clarifications and modifications [DS6], as in P28's (age 11) sketch with their teammate: *"We designed for this e-highlighter function, so that you can highlight the bit where you find confusing or don't like. Like them guessing that you like fast food, the website would then go back and review that assumption they made about you."* Some still more active designs were when the (typically older) child expressed a desire to control and personalise how data profiling is computed about them: instead being treated as passive recipients that can only configure things once all the datafication is done, children proposed ways to actively engage in the whole datafication process. Such mechanisms included designs that support them to *"choose which pages I visited can be used to generate my profile"* (P38, age 14) [DS7]; *"deciding the models used to build my profile, like I can assign a value on how much this thing I did online matters, or if that's just a random thing I did."* (P51, age 10) [DS4]. Similarly, instead of just being told how their profiles might be shared with other platforms, a group of children [DS6] designed for mechanisms that they can create a list of platforms themselves, deciding on who can have their profile or not.

4.3.3 Call for More Humane Designs. Another theme that emerged from children's design activities was their desire to have positive experience and willingness to build a positive relationship with the platforms. Children expressed their expectations to be treated more equally and more humanely by the platforms: *"If the platforms were humane, which I think they are, which I hope they are. They would know they are dealing with actual people, we are not just statistics in their database or whatever."* (P52, age 10). To start with, children described how they want to have *"more positive experience"* (P12, age 8) on the digital platforms, such as through the use of smiley icons and more friendly tones [DS2]: *"We changed this sentence to 'Will you allow us to recommend you videos based on your profile?'. Because with that, it feels like a nice lady trying to talk to you, unlike a machine just trying to generate info about you."* (P6, age 12). Some children also talked about the use of *"more humane way"* (P43, age 14) of delivering the designs: *"Don't just show me the numbers, it feels really cold."* (P50, age 13). Children expressed great emotions and angers when they felt they are not *"being treated as a human"*: "*I'm being dehumanised. The way they deliver these things [e.g., data policy] ... give me information, but don't care about my reactions at all."* (P51, age 14); *"It feels like all that matters to them is 'me' as my data, like not 'me' as a human-being."* (P2, age 13). One interesting observation we had on children's redesigns is their tendency to personify a platform, almost in an unconscious way. A direct example of this is how often some kind of bot - personified version of the platform would show up in different children's designs (e.g., [DS3], [DS4], [DS9]). Children talked about how they want to be able to have *"actual conversations"* with it, because *"That's what human do, they talk with each other, not just showing each other with numbers and statistics."* (P12, age 8) Other children [DS4] also designed for mechanisms that can *"take care of me, know what I want"* (P18, age 9) — designs that can tell what's personal or secretive to a child and help children to hide these information from the datafication practices, or even mechanisms that can *"protect me when I need it"* - P39 (age 9) redesigned for a mechanisms in which platforms are now able to identify if one's profile contains "sensitive information" and whether such information would cause harmful effect on them. When performing these redesigns, themes including *"friendship"* and *"relationship"* were frequently brought up (e.g., [DS2], [DS5], [DS10]) : *"Treat me as your friend, not just a number in your database"* (P6, age 12).

5 DISCUSSION

5.1 Implications for Children's Digital Literacy Development

Children are often regarded as less capable or competent than adults for coping with the complexities of online life, including aspects of privacy, safety, and datafication [63]. However, through a multi-step co-design workshop, we found that not only do children care significantly about various aspects of datafication, but they demonstrate some rudimentary conceptual understandings of it, and a strong willingness to transform their conceptualisation to concrete design practices. Children in our study demonstrate understandings of various levels while with differences across age groups, confirming the urgency in extending children's critical algorithmic literacy. We observed three key knowledge gaps in children: lack of recognition of their own data rights, data being transmitted across platforms and companies, and the real-world implications of inference being made about them. Our results reinforced existing findings that children do not always comprehend datafication to a full extent [109], and shed a new light on how children's understanding differs in age, which requires age-appropriate support for children's algorithmic literacy development.

The three gaps of knowledge demonstrated by children in different age groups are largely aligned with the three forms of computational thinking in CAL (Section 2.3), namely from *cognitive* thinking (i.e. understanding of basic computational concepts), to *situated* thinking (i.e. situate the abstract computational concepts in context children know and care about), and finally to *critical* thinking (i.e supporting the questioning of larger structures and processes behind the computational phenomenon). The CAL framework provides a useful framework for us to make sense of the different datafication perceptions exhibited by children of younger v.s. older age, and identify future directions to support children's digital literacy development. For the youngest children (7 to 9Yr), our results indicate a need for the design community to focus on informing children of basic computational concepts (e.g, what is data, what is data transmission, what is data processing); such concepts do not necessarily need to be in great depth and go beyond laying down a foundation for children to comprehend more complicated context. This will complement existing focus on using accessible medium (such as cartoons or video material) for younger children [8]. Meanwhile, our findings also resonates the emphasis in CAL that children's computational thinking should go beyond *cognitive* thinking, and *situated* thinking will complement children's understanding of the social aspects of algorithmic systems. This is particularly relevant for the 9+ to 11Yr age group, while such content could appear daunting for some younger aged children. Platforms like Track This [13], which allows children to choose a fictional persona (as an influencer or filthy rich) to explore the impact of datafication, or Interland [12], which creates a virtual context for users to explore a diverse range of digital footprints and their implications, provide good situated thinking scenarios. Other findings, especially from 11+Yr children, demonstrated the importance of introducing *critical* thinking in algorithmic literacy. This ability of situating datafication in a broader digital society is rarely discussed in existing research of algorithmic literacy [65, 85] and can be challenging to facilitate. There is an increased number of tools and technologies supporting children's algorithmic literacy development (such as the UNESCO Algorithm & Data Literacy Project [10]). However, these initiatives rarely provide opportunities for children to play with 'real' data that is meaningful for them or allow them to carry out algorithmic investigations, and we encourage future designers to focus on these two specific aspects, as both of are crucial for pushing children to "conceptualise, create, and disseminate digital projects that break silences, expose important truths, and challenge unjust system" [53].

5.2 Implications for Future Age-Appropriate Designs for Children

Through our co-design activities, we identified a strong need for providing age-appropriate support for children of different ages. Our results showed that the depth of children's understanding of datafication varied significantly between age groups. We found that children in the younger age group preferred simpler designs (cognitive-thinking inspired ones) that offered them more simplified information, helping them to grasp the basic ideas on datafication and its implications. Whereas almost all children in the older age groups preferred designs that are more situated to their actual digital experiences and to provoke their critical-thinking, and showed great willingness towards having more information "related to me" as well as learning about the more in-depth problems behind the datafication phenomena. Our findings provide critical inputs regarding design implications for future age-appropriate designs that support children coping with datafication. We therefore propose that *there is no one-fits-all design solution* when it comes to designing for children. How shall future designers address the various needs in children from different age groups, and how shall they unpack this no one-fits-all design then?

Rethink what 'transparency' means for children of different age groups. To start with, we have observed that, in contrast to how some of the child-specific technologies have been carefully considered according to children's age and developmental needs [3, 31, 42], today's digital platforms have given much less consideration regarding how children should be informed of the ubiquitous datafication behaviours online. This poses a strong need for future designers to *rethink what 'transparency' means for children of different age groups.*. Our co-design activities have particularly focused on exploring the type of data transparency that children would care for and be able to make sense of (as shown by examples in Section 3.1). The general assumption is that children have less awareness about the datafication practice and data-based exploitation in their digital worlds [101, 116]. Our research has shed new lights on this presumption. Children may have less ability to develop the nuanced mental models exhibited in the previous research with adults, however, our observations of how different age groups perceived datafication differently provide important indicators for future design developments: keeping languages simple is rudimentary for supporting younger children (7-9Yr), who also are more likely to need more parental involvement and support; whereas connecting datafication with a child's individual interests or context may provide a more convincing perspectives for designing algorithmic transparency for older children (9Yr+). For 11Yr+ children, we recommend designers to consider scaffolding children for more

in-depth thinking including what are their roles and rights in a datafied society. Future design investigations must be cautious of the age-specific needs from children and a child-centred design approach is crucial to the process.

Reposition children as active participants than passive consumers online. A key insight from our findings is children's strong desire on self-autonomy over their own digital experience and significant willingness to configure the datafication practices on them, as shown in our discussions in Section 4.3. This indicates a strong need to *reposition children as 'active' participants than passive consumers in the process of designing empowerment tools for them.* Designers should consider options to facilitate children to actively engage in the various datafication practices (e.g., how a specific video has been chosen for them, how data about them is shared and used); instead of treating them as passive recipients of content. This support should also be considered according to age-specific needs of children. For younger children (7-9Yr), designers should consider allowing children to conduct *direct* control, providing protection for children against the dataficaiton practices not wanted (e.g., a button to turn off all data inference), and avoid hiding such option under layers of menus. We also suggest designers to offer children *direct* guidance on what would happen is a certain choice is made and send out alerts and notifications in a more visible way. For the slightly older children (9+ to 11Yr), many children expressed their desire for real-time support as they make choices online, which could be better supported with mechanisms such as just-in-time visualisations of how choices could effect their online experience (e.g., a visualisation on the changes in recommendations). Older children (11Yr+) demonstrated a strong need for more fine-grained control, as they seek ways to actively shape their own dataficaiton experience. These children also demonstrated tendency to seek help from their peers instead of parents, and thus setting up mechanisms for peer support or for informing children of their data rights may be more meaningful.

Demonstrate care and respect. Another interesting theme observed from our findings is children's great willingness in building a *"positive relationship"/"friendship"* with the online platforms, and their desire in being treated in more humane ways - they want to be treated as a human, not *"a random number in the database"*. Such an expectation echoes with the recent line of work in UX literature around designing for dignity/humane by design, which promotes designing systems so that users experience dignity throughout the system, and its core holding is that designers must view users not just as a means to making capital, but treat them with respect and dignity themselves [2, 11]. Children expected themselves to be respected and taken care of by the platforms. For the younger children (7-9Yr), they require "positive elements" to reinforce this reassurance, such as through smiley icons and nicer tones. An interesting finding is that the children consistently conceptualise ways for platforms to have conversations with them, and respond in a human-like manner (e.g., human characterstics). Prior studies have showed that personified voice assistants with traits such as different accents and personalities could be more favoured by young children [47]. Mechanisms such as using basic conversational elements to present information or respond to choices made (e.g., "You did a great job!") could be an effective direction to explore for younger children. However, such approaches must ensure children's innocence is protected but not exploited and guided by careful, ethical considerations (further discussions in Section 5.3). Older children (9+ above) are keen to receive explanations that show them how things have been done in their best interests, and demand themselves not to be treated as numbers. Future designs should consider providing more than factual details, and complement such with contextualised explanations on how and why things are done. Designers should also consider allowing children to respond to information given and decision made for them (e.g., "I don't agree with this" button), and accommodate their requests in an equal and respectful way.

5.3 Towards Future Data-driven Digital Experiences for Children

Our observations of children's current experience and perceptions of datafication prompted the need for rethinking what future data-driven digital experiences should be like for children. One interesting observation was children did not only want to be meaningfully informed about their data, but they wanted the informant to be humanoid in some way. Such findings echo with previous research, that children interact with virtual agents differently than adults, and they tend to have social exchanges (e.g., "bye! Google!") [24] and emotional interactions (e.g., "I love you, Alexa!") [47] with systems, and could refer to virtual agents with person pronouns more often than those adult users [88]. Children want to be treated with respect and they demand to be treated as equal human-being. It is perhaps therefore not surprising that when coming up with solutions and design alternatives, children tend to believe that their wish will be fulfilled if the data-driven platforms were human. While such ideologies provide new design opportunities for children's experience online — personified voice assistants with traits such as different accents and personalities were found to be more favoured by children [47], the innocence and willingness to establish friendships with platforms exhibited by children also called for the need on greater safeguarding measures and more cautious designs — it should be protected, not exploited. While humanising these platforms seemed wonderful at first glance, there is an implication that trust can be misused to further monetisation priorities, while exploiting people (children) who are most vulnerable. Existing research within the children-robot interaction community suggest that children can develop trust and affection on humanoid robots [23, 67, 102, 105]. While these studies found that children could find it easier to approach a humanoid with their problems than approach an actual human [94, 96]. It was also suggest that children could more likely to share secrets or problems which they would normally not share [20, 111]. It was found that when too much personification is embedded, children could feel deceived when humanoid pass on the information being told [97, 111]. In the meantime, to autonomously detect which information was told in secrecy (as was suggested by some of our children participants), sophisticated speech recognition would be required, and existing approaches are yet to work reliably with children [55]. We therefore call for attention to the designers community to carefully consider their design choices – What happens when we give data personality? What happens when data is not just used to inform children, but children develop trust with data that can be breached? While

there has yet to be complete answers to these questions, we urge future designs to not simply focus on exploiting children's willingness in building positive relationship through simple personification designs (e.g., using human-like voices or calling out names), but build systems and platforms in ways that genuinely care about children, treating them with respect and providing them with the care and support that they need.

Children's expectation in respect and care directly relates towards children's desire for greater data autonomy online. In our study, both children's proposed solutions to perceived problems in the fictional inquiry sessions and their designs in the feature redesign sessions confirmed and echoed with previous findings on children's desire for more legibility and control [109]. Children's expressed a need for means to learn more about and to effectively control their data online marks a strong call for greater data autonomy from children. As pointed out by many children in our study, the current datafied society demands a fundamental shift of the current data ecosystem (*"a revolution is needed"* P32, age 13). They believe that the key contributing factor to the current ubiquitous datafication in their lives, as well as our society, is the centralised data monopoly and concentration of power by a number of platforms (*"1% companies controlling 98% data"* P53, age 14). A strong theme of data activism emerged from children's discussion, and these "young data activists" are demanding actions to be taken. Data activism here refers to the recent movement in which citizens are becoming increasingly engaged in the range of socio-technical practices that interrogate the fundamental paradigm shift brought about by datafication [75]. While the notion of data activism is not entirely new and dates back to discussion around the democratic agency of things [60, 66] and directly relates to this new wave of decentralised paradigms for data sharing and ownership, which seeks to expand individual data subjects' ability to control access to their data [7], our work is the first to identify such data activism in children, possibly even stronger than adults.. Previous research have attempted to address children's autonomy online mainly through supporting them with improved behavioural autonomy [32, 43, 45], such as dealing with excessive nudging or data-based behaviour manipulations, within the existing data ecosystem, which undoubtedly is important. However, our work suggests that such support is probably not sufficient when children demand for more fundamental changes to be taken and more fundamental autonomy to be re-gained. This provides crucial inputs to the current research regarding supporting children's digital autonomy, and we encourage future research make further explorations regarding how to design for mechanisms that help children regain their data rights, and how children would want a future, more humane and autonomy-supportive data ecosystem to look like.

6 LIMITATIONS AND FUTURE WORK

There are several important limitations of this work, including self-reporting data in the pre-design activity, the study length and the use of a fictional storyline. We have attempted to mitigate these limitations through several ways. We correlated children's self-reported perception and experiences with their responses in the design activities, to identify any potential misconceptions or gaps of knowledge, which led to our key finding regarding the importance of age-appropriate designs. To avoid overburdening our participants, our study sessions were designed to last no longer than 1.5 hours, which may affect children's ability to recall knowledge. Researchers were briefed to pay particular attention to quieter children and encourage their inputs, and group activities are regarded as more effective to prompt knowledge sharing and recall. Children were reminded there are no "right way" of redesigning features they want, and we endeavoured to ask questions in a language appropriate for the participant's age and development. Finally, we acknowledge that our introduction of YouTube "elf" in the storyline may relate to our findings about children's tendency towards personifying online platforms. However, we believe such potential nudge may not affect our findings much, as children's tendency towards personifying non-living objects dates well back to their early stage development such as how they personify puppets/toys [95], and thus is not uniquely triggered by our study setting. Furthermore, our finding was more nuanced and showed children's desire to be *treated as equal human-beings*, which is a demand for more autonomy and humane-design, than simply viewing the platforms in a personified way.

Future work aims to explore how we may integrate the identified design implications to existing features on the online platforms, and develop ways to support children's tendency towards data autonomy. We intend to develop prototypes following the identified design implications, exploring flexible scaffolding for children's diverse needs and their effects on children. Meanwhile, we aim to explore more ways for supporting the data activism in children as well as supporting their data literacy development.

7 CONCLUSION

As children are growing up in an age of datafication, children's data are now being routinely used to profile, analyse and make predictions of them. Their actions online are not only recorded, tracked, aggregated, but also analysed and monetised. Such practices are hard to understand even by adult users, let alone children. This paper is the first to contribute an understanding of how children aged 7–14 would like to be supported when coping with datafication practices. Through 10 co-design sessions with 53 children, we identified children's envisioning and demand from platforms for coping with datafication, followed by their desired concrete design practices, including age-related needs for more informed choices, call for more humane designs, and autonomy-supportive designs for more active engagement. Our findings provide crucial insights for creating age-appropriate support for children's algorithmic literacy development, highlighting and unpacking the importance of no one-size-fitting-all designs to support children's coping with datafication. We contribute a first understanding of how children aged 7–14 would like to be supported with datafication and what future data-driven digital experiences should be like for them, who demand a shift of the current data ecosystem towards a more humane-by-design and autonomy-supportive future. We hope that our findings will support future designing for children in accommodating their diverse needs, and lay down the foundation for a more ethical data governance structure for children in the future.

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A APPENDIX

Age		Gender		Ethnicity		Type of School	
7 - 11Yr	25	Boy	29	Asian	13	Grammar	15
12 - 14Yr	28	Girl	24	Asian/Black	1	Private	21
				Asian/White	2	State	17
				Black	12		
				Hispanic	3		
				White	22		

Usage Behaviours			
<5 hr/week on YouTube	16	Use own account	7
5 - 10 hr/week on YouTube	20	Use parents' account	15
> 10hr/week on YouTube	17	Use siblings' account	5
		Visitor Mode	26

School & Family Education related to Topics around Datafication (if mentioned)	
Parents had conversations on related topics	20
Have courses on related topics at school	21
Did not mention	26

Table 1: Summary of participants' demographic information

Redesigned YouTube Mechansims	Dimension of Change	Cognitive-Thinking Version	Situated-Thinking Version	Critical-Thinking Version	Comparison to Current Version of the YouTube Platform
Video Recommendations on Homepage	**Transparency**	show basic category of the data being collected and used to generate video recommendations	show data being collected and used to generate video recommendations, contextualising these data within children's personal experience on YouTube	explain the bigger picture behind video recommendation, that the recommendations are based on profiling of data collected on YouTube	No such design (information on basic category of data collected and used can only be found in the data policy)
	Control	offer control on turning on/off video recommendations based on basic category of the data collected	offer control on turning on/off the video recommendations based on data collected, offer control on stop collecting types of data. Contextualising such controls within children's personal experience on YouTube	offer control on turning on/off the video recommendations based on profiling, offer control on making changes to the profiling	No such design
Personalised Advertisements at the Beginning of Videos	**Transparency**	show basic category of the data being collected and used to generate personalised ads	show data being collected and used to generate personalised ads, contextualising these data within children's personal experience across multiple online platforms	explain the bigger picture behind personalised ads, that the personalisation are based on profiling of data collected across multiple online platforms	Similar to cognitive-thinking version
	Control	offer control on turning on/off personalised ads based on basic category of the data collected	offer control on turning on/off the personalised ads based on data collected, offer control on stop collecting types of data from other online platforms. Contextualising such controls within children's personal experience across multiple online platforms	offer control on turning on/off the personalised ads based on profiling, offer control on making changes to the profiling	No such design (one can only control personalised ads in their Google account, not specific to YouTube and do not offer control on making changes to the profiling)

Figure 4: This table describes our redesigns of the 12 mechanisms on YouTube. We created 6 mockups for each mechanism, split between transparency and control, and with different design thinkings inspired by the CAL framing: cognitive, situated, and critical. See Figure 5 for graphical representations.

	Participant ID	Age	Gender	Ethnicity	Type of School	Usage Behaviours	School & Family Education related to Topics around Datafication (if mentioned)
Session 1	P1	14	Girl	White	Grammar	>10 hr/week on YouTube, use own account	Parents had conversations about data safety at home; Have courses on data privacy at school
	P2	13	Girl	Black	Private	>10 hr/week on YouTube, use parents' account	Don't recall having conversations with parents on related topics; Have courses on data privacy at school
	P3	11	Boy	Asian	Grammar	5-10 hr/week on YouTube, use parents' account	[Did not mention]
	P4	8	Girl	White	State	<5 hr/week on YouTube, visitor mode	Parents had conversations about online privacy at home; No such course at school
	P5	7	Boy	White	State	5-10 hr/week on YouTube, visitor mode	[Did not mention]
Session 2	P6	12	Boy	Asian	State	>10 hr/week on YouTube, visitor mode	[Did not mention]
	P7	12	Girl	White	State	>10 hr/week on YouTube, use parents' account	Parents had conversations about online privacy at home; No such course at school
	P8	14	Boy	Hispanic	Private	5-10 hr/week on YouTube, visitor mode	Parents work in related fields; Have courses on online safety at school
	P9	11	Boy	White	Grammar	5-10 hr/week on YouTube, use sibling's account	Parents work in related fields, talked about related issues at home; Have courses on online safety at school
	P10	8	Boy	Black	State	5-10 hr/week on YouTube, visitor mode	[Did not mention]
	P11	7	Girl	Asian	Private	<5 hr/week on YouTube, use parents' account	[Did not mention]
Session 3	P12	8	Girl	White	Private	<5 hr/week on YouTube, visitor mode	Had conversations with older sibling about data privacy; Have courses on data privacy at school
	P13	12	Girl	Asian	Private	>10 hr/week on YouTube, visitor mode	[Did not mention]
	P14	14	Boy	Hispanic	State	>10 hr/week on YouTube, use own account	Set up own YouTube Channel; Have courses on online safety at school
	P15	13	Boy	White	State	>10 hr/week on YouTube, use sibling's account	Had conversations with older sibling about data privacy; No such course at school
	P16	10	Boy	Black	Grammar	<5 hr/week on YouTube, visitor mode	[Did not mention]
	P17	11	Girl	Asian/White	Private	5-10 hr/week on YouTube, visitor mode	[Did not mention]
Session 4	P18	9	Boy	White	Private	<5 hr/week on YouTube, visitor mode	Have many IOT devices at home, did research on them with parents; Have courses on data privacy at school
	P19	10	Girl	Black	State	5-10 hr/week on YouTube, use parents' account	[Did not mention]
	P20	11	Girl	Black	Grammar	5-10 hr/week on YouTube, visitor mode	[Did not mention]
	P21	13	Boy	Asian	Private	5-10 hr/week on YouTube, use parents' account	Parents had conversations about data safety at home; Have courses on data privacy at school
	P22	14	Boy	White	State	>10 hr/week on YouTube, use own account	[Did not mention]
Session 5	P23	9	Boy	White	State	>10 hr/week on YouTube, visitor mode	[Did not mention]
	P24	10	Girl	Asian/White	Private	<5 hr/week on YouTube, visitor mode	Parents had conversations about online privacy at home; No such course at school
	P25	11	Girl	Asian	Grammar	<5 hr/week on YouTube, use sibling's account	[Did not mention]
	P26	12	Boy	White	Private	5-10 hr/week on YouTube, visitor mode	[Did not mention]
	P27	14	Boy	Black	State	>10 hr/week on YouTube, visitor mode	Parents work in related fields, talked about related issues at home; Have courses on online safety at school

Table 2: Individual participant's demographics (co-design session 1–5)

	Participant ID	Age	Gender	Ethnicity	Type of School	Usage Behaviours	School & Family Education related to Topics around Datafication (if mentioned)
Session 6	P28	11	Girl	Asian	Private	>10 hr/week on YouTube, visitor mode	Don't recall having conversations with parents on related topics; Have courses on data privacy at school
	P29	11	Boy	Asian	Grammar	<5 hr/week on YouTube, visitor mode	Parents had conversations about data safety at home; Have courses on data privacy at school
	P30	12	Girl	White	Grammar	5-10 hr/week on YouTube, use parents' account	[Did not mention]
	P31	12	Girl	Black	Private	5-10 hr/week on YouTube, visitor mode	Parents work in related fields, talked about related issues at home; Have courses on data privacy at school
	P32	13	Boy	White	State	>10 hr/week on YouTube, visitor mode	[Did not mention]
	P33	14	Boy	White	Private	<5 hr/week on YouTube, use own account	[Did not mention]
Session 7	P34	13	Boy	Asian	Private	5-10 hr/week on YouTube, use sibling's account	[Did not mention]
	P35	11	Boy	White	Private	5-10 hr/week on YouTube, visitor mode	Parents work in related fields, talked about related issues at home; Have courses on data privacy at school
	P36	8	Girl	White	Grammar	<5 hr/week on YouTube, use parents' account	Parents had conversations about data safety at home; Have courses on online safety at school
	P37	12	Girl	Black	State	<5 hr/week on YouTube, visitor mode	[Did not mention]
	P38	14	Boy	Asian	State	>10 hr/week on YouTube, use own account	Parents work in related fields, talked about related issues at home; No such course at school
Session 8	P39	9	Boy	White	State	>10 hr/week on YouTube, use parents' account	[Did not mention]
	P40	11	Girl	Black	Grammar	5-10 hr/week on YouTube, visitor mode	[Did not mention]
	P41	12	Girl	Asian	Private	>10 hr/week on YouTube, visitor mode	Parents had conversations about data safety at home; Have courses on data privacy at school
	P42	13	Boy	White	Grammar	<5 hr/week on YouTube, use parents' account	Parents work in related fields, interested in Tech Law himself; Have courses on data privacy at school
	P43	14	Boy	White	Private	5-10 hr/week on YouTube, use own account	[Did not mention]
Session 9	P44	9	Girl	Black	Private	<5 hr/week on YouTube, use parents' account	[Did not mention]
	P45	14	Girl	Hispanic	Grammar	>10 hr/week on YouTube, visitor mode	[Did not mention]
	P46	10	Boy	Asian	State	<5 hr/week on YouTube, use parents' account	Parents had conversations about data safety at home; Have courses on online safety at school
	P47	12	Boy	White	Private	5-10 hr/week on YouTube, use sibling's account	[Did not mention]
	P48	13	Girl	Black	Grammar	5-10 hr/week on YouTube, use parents' account	Don't recall having conversations with parents on related topics; Have courses on data privacy at school
Session 10	P49	9	Girl	Asian	State	5-10 hr/week on YouTube, visitor mode	[Did not mention]
	P50	13	Boy	White	Private	<5 hr/week on YouTube, use parents' account	Don't recall having conversations with parents on related topics; Have courses on data privacy at school
	P51	14	Boy	Asian/Black	Grammar	>10 hr/week on YouTube, visitor mode	Parents had conversations about data safety at home; Have courses on online safety at school
	P52	10	Girl	White	Private	<5 hr/week on YouTube, use parents' account	Don't recall having conversations with parents on related topics; Have courses on data privacy at school
	P53	14	Boy	Black	Grammar	5-10 hr/week on YouTube, use own account	[Did not mention]

Table 3: Individual participant's demographics (co-design session 6–10)

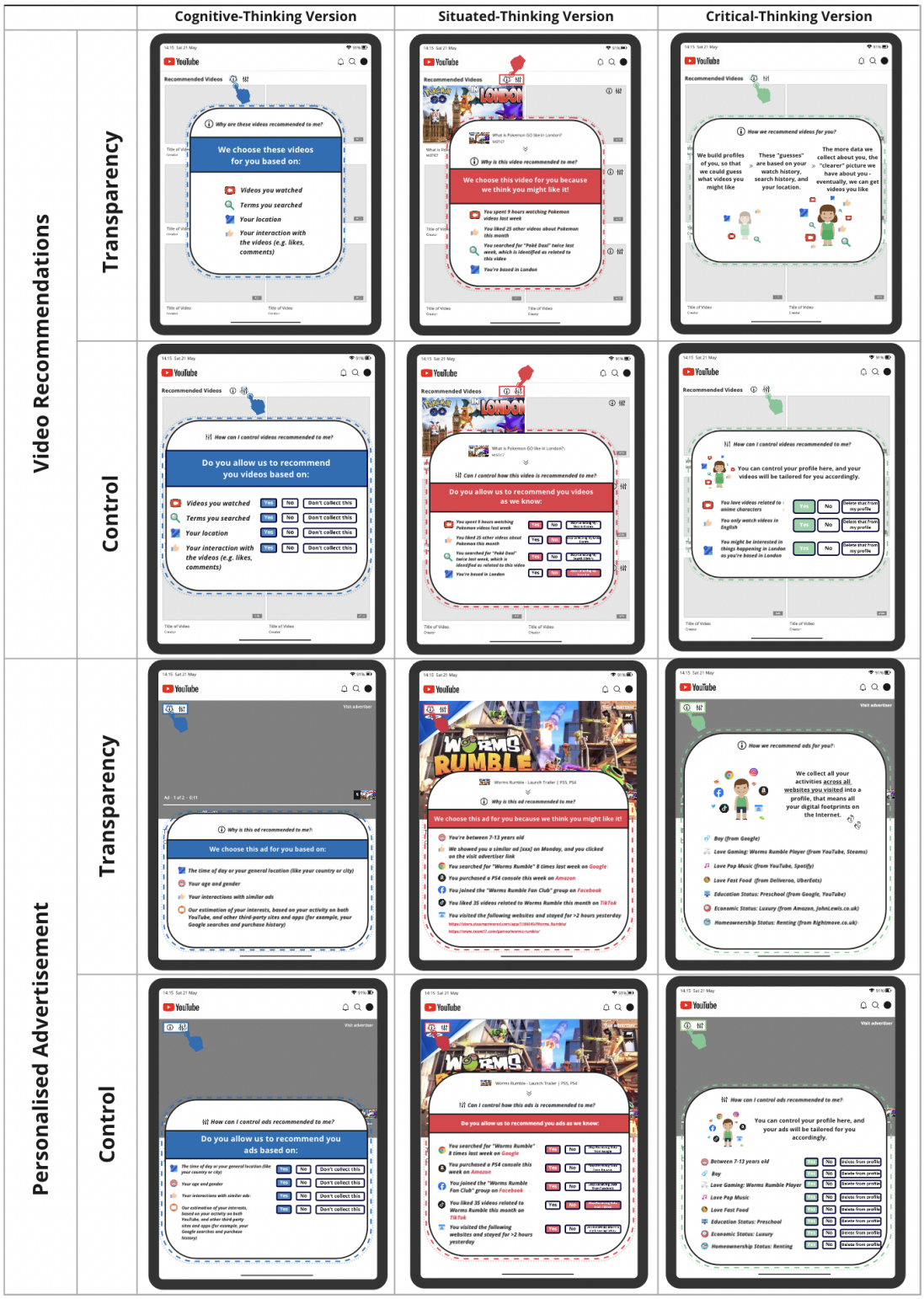

Figure 5: 12 Mockups of Changes to Mechanisms in the YouTube Platform