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Building the design ICT inventory (DICTI): A Delphi study

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ABSTRACT

The use of Information and Communication Technologies (ICTs) for people with Neurodevelopmental Disorders (NDD) is increasing; however, it is currently hard to assess its quality as there are issues regarding the lack of consensus on how to design these technologies. Here, using a Delphi method, we built a *trans*-ICTs inventory named the Design ICT Inventory (DICTI) to guide and gauge design in the 4 main ICTs dedicated to people with NDD (serious game/App, robotics, video modeling, augmentative and alternative communication). After two rounds with feedback from 12 experts, we obtained consensus and agreement for each of the 13 items of the inventory: customization; feedback; rewards; contextualized learning; enhance motivation; manage difficulty; increasing accessibility; clarity of instruction and content; attention capacity; clear goals; minimalistic graphics and audio; human interaction; and trustworthy. The DICTI provides an easy tool to use in order to assess the design of ICTs. Future research is needed to ensure the inter-reliability of the inventory and its relevance in assessing ICT.

1. Introduction

Neurodevelopmental disorders (NDD) are a group of conditions characterized by delays in developmental domains such as social and communication skills, intellectual and executive functioning, motor skills and behavior (American Psychiatric Association, 2015). People with NDD may have mild to severe impairments in academic learning, social and personal functioning, and autonomy (American Psychiatric Association, 2015). According to the timing of the earliest clinical expression, they include intellectual disability (ID), Autism Spectrum Disorder (ASD), communication disorders (CD) that show first symptoms during infancy and toddlerhood, specific learning disorders (SLD), motor coordination disorders (MCD) and Attention Deficit/-Hyperactivity Disorder (ADHD) that usually start later during childhood (American Psychiatric Association, 2015). Such NDD are frequently combined with other NDD comorbidities, resulting in multidimensionally impaired children (Xavier & Cohen, 2020). The use of Information and Communication Technologies (ICTs) for people with NDD has increased over the last 20 years (Grossard et al., 2017). Many ICT supports are used with this population: computer, mobile devices like smartphone or tablet, screen, robots, or virtual and augmented reality. They can take multiple forms as serious games or apps, assistive technologies, or immersive reality. They can target a wide range of skills or behaviors such as social and communication skills, academic knowledge, sensory and motor skills, autonomy and inclusion, emotion recognition, production, or regulation (Boucenna et al., 2014; Grynszpan et al., 2014; Valentine et al., 2020). They can be used in diverse settings including care centers, schools, or at home (Khan et al., 2019; Miguel Cruz et al., 2017). ICTs are generally well accepted by parents and professionals but also by children or adolescents with NDD (Richardson et al., 2018; Valentine et al., 2020). However, few studies have targeted adult users (Valentine et al., 2020).

ICTs seem to be promising tools to help people with NDD in their daily life. However, it is important to remember that these results have to be taken with caution because of the methodological limitations of the studies conducted in the field (Grynszpan et al., 2014; Khan et al., 2019; Moon et al., 2020). There are many reasons that can explain the difficulty to assess ICT tools: (i) the poor quality of studies with small sample sizes (Khan et al., 2019; Moon et al., 2020), (ii) the lack of framework to guide the design in ICTs, resulting in an important heterogeneity among ICT tools (Carlier et al., 2020; Khowaja & Salim, 2020) and (iii) a large variety of methods to assess these technologies (Grossard et al., 2017;

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Whyte et al., 2015). Guidelines aiming to improve studies' methodology based on evidence-based approach are not sufficiently developed (Zervogianni et al., 2020), causing literature to be more limited in regard to ICT tools' design. Indeed, an important component in evaluating and helping to improve the quality of ICTs research revolves around design choices. Reviews on how to design ICT tools for people with NDD are rare. Some authors have already proposed some frameworks, but they are often proposed to a specific population, a specific ICT and specific targeted skills, which prevents them from being widely used (e.g. Carlier et al., 2020 focus on the creation of a serious game to reduce anxiety in children with ADHD; Khowaja & Salim, 2020 focus on a serious game aiming to improve vocabulary in children with ASD). Moreover, one question remains: "what are the active components of digital health intervention?" (Hollis, 2017) where active components are defined as components that have the predicted impact on the targeted outcome. Currently, no study is able to answer that question. In particular, there is no scale that can assess and score the quality of an ICT tool in terms of its design.

The Delphi technique is "a structured process that uses a series of questionnaires or 'rounds' to gather information" (Jorm, 2015). This method is appropriate when there is a lack of evidence or incomplete knowledge (Powell, 2003). It allows obtaining an expert consensus and that can be used to determine which methodologies are appropriate in medical science (Jorm, 2015). Usually, consensus is defined by a percent of agreement with a threshold of 75%, however this definition varies from one study to another (Diamond et al., 2014). In a review including 80 Delphi studies, median scores above a predefined threshold and a high level of agreement (i.e., percent of overall rating are in the highest tertile) are the most frequent method used to achieve consensus (Boulkedid et al., 2011). Even if no agreement exists regarding best criteria for obtaining consensus, a measure of distribution and a central tendency should be included. Medians appear to be more robust than means and IQR are more robust than standard deviation (Trevelyan & Robinson, 2015). The criteria of consensus should be given a priori with a limited number of rounds that should be stated prior to the Delphi study (Diamond et al., 2014; Trevelyan & Robinson, 2015). Participants received results after each round. Visual feedbacks as bar charts help with interpretation (Trevelyan & Robinson, 2015).

The Delphi method has the advantage of not requiring face-to-face contact, which facilitates wider group participation, and it allows recruiting experts, despite of their geographical location (Trevelyan & Robinson, 2015). A clear explanation should be given as to why they are considered experts. In the mental health area, experts are generally professionals (Jorm, 2015). The panel of experts should be around 20 or more participants to assure a good stability of the results. However, Delphi studies in mental health have generally much smaller panels (Jorm, 2015). Recruited experts from different backgrounds allow to produce better quality solution than homogenous groups; but, concerning clinical interventions, specialists of the specific area seem to be more appropriate (Powell, 2003). The recruitment of experts should be done based on the definition of expertise and not only on the acquittance with the researcher (Powell, 2003).

The questionnaire is generally administrated by a web survey which allows to recruit experts everywhere in the world without needing to meet virtually or in person (Jorm, 2015). Lickert scale from 1 to 9 is the more common method used in Delphi studies (Boulkedid et al., 2011). The Delphi method has already been used with those with NDD (i.e. Ali et al., 2018) and for new technologies in healthcare (i.e. Polisena et al., 2018). Zervogianni et al. (2020) have already used a Delphi method to develop a consensus on what is good evidence for ICT for people with ASD, but their work did not focus on the design of ICT.

This study is based on the Delphi method and aims to fill the gap in assessing designs concerning ICTs by creating an inventory to rate it. We first constructed a *trans*-ICT inventory based on the literature named the Design ICT Inventory (DICTI). We refer to the *trans*-ICT inventory as a tool easily adaptable from one tech to another (e.g. from serious game to robotics) by keeping a common structure and specific examples to rate the inventory according to each specific tech or modality. We first described how we identified targeted components of digital intervention and linked them to each item of the inventory thanks to a review of literature. Then, we explained how we conducted the Delphi study by collecting experts' opinions from different backgrounds and ran three rounds of modification and experts' rating in order to obtain a consensus on the inventory. We finally discussed the interest of our work and its limitations regarding the need of validation and replication of these findings.

2. Materials and methods

2.1. Selection of the items for the trans-technology inventory based on a literature review

We first constructed the *trans*-technology inventory thanks to a literature review on ICTs and NDD. Between October 29th, 2020 and November 2nd, 2020, we explored the PubMed Database with the following key-words and combinations ("design" OR "methodology" OR "framework" OR "protocol") AND ("neurodevelopmental disorder" OR "developmental disorder" OR "developmental disabilities" OR "autism" OR "developmental disorders") AND ("new technologies" OR "digital health" OR "eHealth" OR "technology based intervention" OR "technology" OR "technologies" OR "Information and communication technology" OR "ICT" OR "robot" OR "innovative technology").

We used the following criteria to select the studies: (i) they discussed how to design a tool when creating one; (ii) they reported on ICTs; (iii) they targeted individuals with NDD; and (iv) the papers were written in English. We included journals' articles, book chapters, and conferences proceedings. We excluded papers that do not have a focus on design implications; papers describing the design of their tools without discussing it and its implication for the adaptation of technologies to people with NDD; and papers about cerebral palsy. In addition, we excluded papers focusing exclusively on sensor technologies (as eyes or movement trackers, sleep assessment devices) as well as papers focusing on prosthesis or orthosis. Finally, we excluded all papers describing tools that are not in direct interaction with people with NDD: (i) tele-practice tools not designed for this population; (ii) tools for data collection as fMRI, EEG …; (iii) devices dedicated to parents or clinician (as guidance or screening).

The diagram flow is shown in Fig. 1. We found 131 articles and after screening abstracts we kept 28 articles to construct the scale. In addition to the references listed, we identified 1 additional study that met out inclusion criteria. All articles are summarized in Table 1.

Then, from the 28 articles, we listed all design components or features that the authors defined as crucial for designing a tool for individuals with NDD (see Table 2). Finally, we kept all features cited in at least 3 papers, giving us 12 features for the inventory as follows: customization, feedback, rewards, contextualized learning, enhance motivation, manage difficulty, increasing accessibility, clarity of instruction and content, attention capacity, clear goals, minimalistic graphics, and audio and human interaction. Our team decided to add one last point about trustworthy, which can be defined as the level of trust people have in ICTs to achieve the goal they are made for (Langer et al., 2019). This is a very important feature in robotics but not really considered in the other ICTs.

2.2. Construction of the trans-technology inventory

Based on these 13 essential features (12 from the literature selection plus trustworthiness), we constructed an inventory easy to use and adaptable to assess the presence or absence of each item within the different ICTs. The inventory appears as a matrix with two dimensions:

As we aimed to obtain a *trans*-ICT inventory, the first dimension is composed of the most common ICT's we found in the NDD literature (i.e.

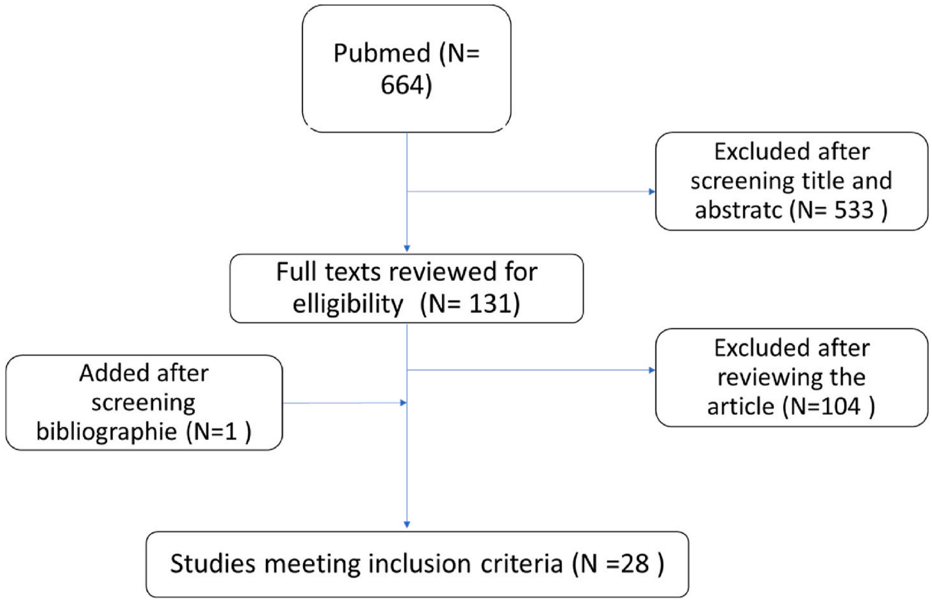

Fig. 1. Flow-chart of the study search.

Table 1
Characteristics of the studies used to construct the *trans*-technology inventory.

Authors, year	Study design	Targeted population	Type of support	Targeted skills
Allen et al. (2016)	Systematic review and case study	ASD	Tablets	Communication Learning skills
Carlier et al. (2020)	Case study	ASD	Tablets	Anxiety
Dalton (2016)	Interviews		Robots	Social skills
Dawe et al., 2019	Systematic review		Robots	All skills
Ganz et al. (2017)	Meta analysis	ASD and ID	Tablets	Communication Social skills
Grossard et al. (2017)	Systematic review	ASD	Serious games	Social skills
Grynszpan et al. (2014)	Meta-analysis	ASD	Serious games	Social skills
Guard et al. (2019)	Case study	Developmental disabilities	Tablets	Pain evaluation
Gyori et al. (2015)	Group of studies	ASD	Smartphones	Social skills Daily living skills
Hollis et al. (2017)	Meta-review	ADHD ASD	All digital interventions	All skills
Khan et al. (2019)	Meta-analysis	all NDD	Web based interventions (tablet and computers)	All skills
Liang and Wilkinson (2018)	Group of studies	ASD Down syndrome	Computers with eye tracking	Communication
Light and McNaughton (2012)	Review	Complex communication needs	Apps	Communication Language
Miguel Cruz et al. (2017)	Systematic review	ASD	Robots	All skills
Moon et al., 2020	Meta-analysis	ASD	Smartphones	All skills
Morin et al. (2018)	Systematic review	ASD ID	Tablets and smartphones	Communication
Odom et al. (2015)	Systematic review	ASD	All supports	All skills
Park et al. (2019)	Systematic review	ASD	Virtual reality	All skills
Parsons et al. (2019)	Case study	ASD	Tablets	Visual motor Language Social skills
Pennisi et al. (2016)	Systematic review	ASD	Robots	Social skills
Powell et al. (2019)	Interviews	ADHD	Serious games	Self management of ADHD
Quezada et al. (2017)	Group studies	ASD	Tablets	Motor skills
Root et al. (2017)	Systematic review	ASD	Computers	Academic skills
Sandbank et al., 2020	Meta analysis	ASD	All supports	All skills
Scassellati et al. (2012)	Review	ASD	Robots	Social skills
Tang et al. (2019)	Interview	ASD	Serious games	Emotion recognition
Whyte & Scherf (2015)	Systematic review	ASD	Computers	All skills
Zervogianni et al. (2020)	Interview	ASD	All supports	All skills

ASD: autism spectrum disorder; ID: intellectual disability.

Grossard et al., 2017, Powell et al., 2019; Whyte & Scherf, 2015). We classified them in 4 subcategories: (i) Serious games and Apps (SGA) which are games with an educative purpose (Whyte et al., 2015), (ii) Robots and more precisely assistive robotics and social robotics (Scassellati et al., 2012), (iii) Augmentative and Alternative Communication (AAC) which, among others, refers to a wide variety of technologies which supports communication in individuals with complex communication needs (Wilkinson & Madel, 2019) and (iv) Video Modeling (VM) who are technologies aiming to support independent performance of individuals with special needs (Odom et al., 2015).

The second dimension is composed with the 13 items to rate. Each item can be rated using a Likert-scale between 0 (absence) and 2 (fully considered). To help raters score, each item was connected to targeted skills that ICTs design aims to support. We identified 10 targeted skills:

Table 2
List of features found in the 28 studies from the literature review.

Essential features		
Features	Examples	Studies
Customization: learner's control and choice	Customize the characters and the environment Customize pictures Control some function in the game like duration or order of the exercises Nonlinear gameplay Different pathways in function of the profile Personalized messages Personalized content as possibility to photograph objects in AAC	Carlier 2020; Whyte 2015; Grossard (2017); Dalton, 2016; Tang (2019); Parsons (2019); Powell (2019); Zervogianni (2020); Hollis (2017); Allen (2016); Strickland 2007;
Feedback must be clear that the goal has been reach	Specific sound when the answer is correct No negative feedback Progression bar	Carlier 2020; Whyte (2015); Grossard (2017); Tang 2019; Powell (2019); Strickland 2007;
Rewards	There should not be penalty points Obtain new objects System of points to obtain objects or customize the game Providing encouragement	Carlier 2020; Whyte (2015); Grossard (2017); Tang 2019; Powell (2019)
Gamification with storyline: to enhance motivation and contextualized learning	Including a companion or an enemy in the game Real life scenario Joke or humor The storyline must not be too complex to avoid the child losing the main goal of the game Downloadable gaming resources	Whyte (2015); Tang (2019); Carlier (2020); Grossard (2017); Parsons (2019); Powell (2019)
Evolving task: increasing gradually the level of difficulty for each exercise and from an exercise to another in function of the player	Construct the game to automatically adapt to the level of the player Allow the user to adapt manually the difficulty. This adaptation must be easy and quick: if the change of level is difficult or time consuming between games, there's a risk of losing the player. The game must be challenging but accessible Scaffolding: providing assistance to help the player when a task is hard or new. Then decrease the scaffolding Implementing « auto correct » and « multi-choice options » to support player during difficult games	Carlier 2020; Whyte (2015); Grossard (2017); Tang 2019; Powell (2019); Zervogianni (2020); Allen (2016)
Simplicity to use to promote accessibility	Minimize the number of gestures require Simple gesture needed Familiar hardware i.e. Repetitive placement of buttons Easy to use even for non-technologically advanced people Be compatible with accessibility features available like zoom or voiceover on iPad Taking into account required motor skills and action (drag, swipe …) Taking into account visual-perceptual characteristics of the display regarding visual skills of the population Taking into account cognitive skills as non-verbal comprehension, memory … Simplicity to use for parents or caregivers: avoid time consuming apps	Dalton, 2016; Parsons 2019; Khan 2019; Zervogianni 2020; Guard 2019; Quezada 2017; Strickland 2007; Liang et al., 2018; Light et al., 2012
Clarity of the instructions and content	Short instructions Tutorial Language suitable to developmental age Visual symbols easily comprehensive (Light 2012 AAC) No figure of speech Reminders during tasks Using video instead of pictures could help representing actions	Carlier 2020; Grossard (2017); Powell (2019); Strickland 2007; Light et al., 2012
Attention capacity	Diminish transition time between games (i.e. loading) Using dynamic stimuli to keep the player awake Avoiding unnecessary distractors	Carlier 2020; Grossard (2017); Strickland (2007)
Clear goals at short and long term	One unique goal per gaming session (Carlier, 2020) Differentiate immediate goal (like goal of a game) and long term goal (like goal of the story)	Carlier 2020; Whyte (2015); Tang 2019; Powell 2019
Minimalistic graphics and audio: keep the environment pleasant but avoid non-essential cues	Avoid non-essential animations to avoid repetitive behaviors Giving the possibility to turn off music or sound effects separately Giving possibility to customize graphics as character font or background color	Carlier 2020; Dalton, 2016; Powell (2019)
Human interaction during the game	Cooperative multiplayer games increase prosocial behaviors Integrating other player may favorize engagement Possibility to receive encouragement from families or friends	Carlier 2020; Whyte, 2015; Powell 2019
Non-essential features		
Predictability: effects must be predictable even if the content can be serendipitous	A random object appears at the end of each task	Carlier, 2020
Repeatability	Practice	Carlier, 2020; Grossard, 2017

motivation, identify the targeted task, learning, generalization, social context, attention, fatigability, repetitive behaviors, social interaction, and accessibility. Then, we offered indications for rating items and provided examples for each of the four subcategories of ICTs.

2.3. Delphi study validation

By using the first version of the DICTI that was theoretically constructed based on the literature review and inputs from our team, we conducted a Delphi study to improve the inventory with inputs from three independent external experts from each ICT's subcategory. We contacted 25 experts and found 12 who would help us with our research. Each expert was identified thanks to our network and the literature review. An individual was deemed an expert if she or he (i) had published at least 2 articles in peer review journals about one of the 4 domains of ICTs that we identified, (ii) had implemented specific ICTs in regards to educational and therapy purposes and published at least 1 one experimental study in a peer reviewed journal. We coupled each expert to an ICTs' subcategory depending on the field in which they have published about (SGA, robots, CAA or VM).

To perform the Delphi study, we created a specific online survey to collect survey responses and followed a three-round approach for the study (Jorm, 2015; Trevelyan & Robinson, 2015). The DICTI was sent to the experts with an online questionnaire that each expert had to fill out anonymously. No meetings with the experts were necessary. For the first round, experts had to rate each item twice on a Likert scale from 1 (totally disagree) to 9 (totally agree). The first rating concerned the item in its globality (all ICTs together), and the second rating concerned only the ICT they were expert in (the subcategory of ICT for which the expert was identified). For each item of the inventory, the experts could add additional comments. Participants responded within 2–8 weeks. All of the experts received a feedback on the results of the first round. As recommended by Trevelyan and Robinson (2015), we provided the score for each item given by the expert, a measure of central tendency (median of the score), and a measure of the distribution (inter-quartile range). We also included a visual feedback with a bar-chart to help the interpretation and the comments of the experts, if any.

Following this first round, conducted between the February 8, 2021 and the March 21, 2021, we worked on all the items to integrate all the comments of the experts' panel. For the second round, conducted between the 29th March and the April 30, 2021, we asked the experts to assess each item again as all of the items were modified following the first round. As for the first round, each expert had to rate each item twice on the same Likert scale previously mentioned. We defined consensus for a given item as the extent to which participants agreed with each other and agreement as the extent which participants agreed with each item. To validate an item, we wanted to reach agreement and consensus for this item. As both of them were reach after the second round, we didn't need a third round.

For the global rating (rating about all ICTs), we evaluated the consensus thanks to the interquartile range (IQR), which is an objective and rigorous way of determining consensus (Von der Gracht, 2012). Consensus is considered as reached if IQR <1.5. The agreement was evaluated thanks to the median that has to be superior to 7 and the percentage of agreement (% of score within the 7 to 9 area) that has to be superior to 90%. Each item that reached agreement and consensus was considered as appropriate. For the rating of the item by ICTs' subdomains (3 experts by ICT), we only used the median to evaluate the agreement with the item in order to be sure that each item of the inventory was adapted to each ICT. We obtained 100% response rate for each item for each round of the Delphi study.

3. Results

Twelve experts composed the panel (8 women and 5 men). They are from all over the world (USA = 4, France = 3, Australia = 1, Cyprus = 1, Switzerland = 1, Turkey = 1, United Kingdom = 1). They were equally distributed among the four subcategories of ICTS (three experts per domain). Their background included child psychiatry, special education, psychology, engineering, robotics, and computational science. Results from the first and second round for the global rating are presented in Table 3. Percentage of agreement represents the percentage of score within the 7 to 9 area of the Likert scale from 1 to 9.

No item was removed or added between round 1 and 2 as (i) a majority of the experts estimated that all items of the inventory were relevant (median for the global rating ≥7 for all items) and (ii) no experts suggested adding an item. However, agreement was not reach for all specific rating by ICT (see Table 4). Finally, every item was modified after the first round to include all the comments of the experts.

After round 1, we identified different types of modifications to be made. (i) Modifying titles of the items: items 6, 10 and 11 have been changed to better fit with all types of ICT (i.e., item 10 "Clear goals for short and long term" became "Clear **steps or** goals for short and long term" to better fit with AAC and VM). (ii) Adding examples: we completed each list of examples with new ones that were suggested by the experts. These features could be specific to an ICT (i.e., item 4, we added in VM "choice between first or third person view") or could be added for all ICTs (i.e. item 13, we added for all ICTs "Impact on the user and its environment should be consider (i.e. how to adapt the device to daily life)"). (iii) Adding precisions: some statements needed to be better defined to assure a good comprehension. It was mostly resolved by adding precisions for each unclear point (i.e. for robot and SG, the example "Provides encouragement" for the item 5 became "Provides encouragement (i.e. saying "good job!"). (iv) Adapting terminology: we modified some terms to better fit with the terminology of each ICT (i.e. using "symbols" instead of "pictures" for items related to AAC). All modifications between round 1 and 2 can be found in supplementary material.

Concerning global rating, a good level of consensus (IQR <1.5) and agreement (median >7) were reached for all the items after round 2. For each ICTs rating, agreement was also reached after round 2. The final version of the inventory can be found in Table 5.

4. Discussion

We conducted a Delphi study in order to reach a consensus about the features that well-designed ICTs tools for people with NDD should provide. The interest of this work is to consider that these features can be related to targeted skills that are considered by the most common ICT subcategories (AAC, robots, VM and SG/App). Based on that, we were able to develop a *trans*-ICT inventory, the DICTI, that can be used to improve the design of ICTs and compare tools in terms of design efforts. In order to facilitate the use of the inventory, we proposed different examples of characteristics that can be related to a specific feature and a specific ICT.

The Delphi technique allowed collecting experts' opinions in the four ICTs subcategories we identified. We asked the experts to assess the inventory twice: one global rating for all ICTs and one rating specific to the ICT falling in their field of expertise (Jorm, 2015; Trevelyan & Robinson, 2015). The global rating allowed us to be sure that each of the items of the inventory were relevant and adapted to a targeted skill we identified. After the second round, all items reached the threshold for IQRs and medians, and we defined to verify consensus and agreement. The specific rating was necessary to ensure that each item was adapted regarding to the targeted ICT. For each ICTs, the median of 7 was reached for all the items of the DICTI (Von der Gracht, 2012).

The creation of the DICTI pursues two main objectives. The first is to provide an efficient tool to guide the design of ICTs and/or gauge the ICT's adequacy to best practices found in the literature. This inventory is relatively short with only 13 items, and no experts suggested adding more features. We believe that the DICTI should be easy to use and relatively quick to rate. The particularity of this inventory is the providing of examples related to each ICT that illustrate each feature and so facilitates the comprehension of what they represent. The objective is to allow anyone to use this inventory without specific training. However, it can only be used after a rater practices using the ICT tool they want to rate. Researchers, NDD's professionals,

Table 3
Results of experts' global rating for Delphi rounds 1 and 2.

Round 1: global rating													
Items	1	2	3	4	5	6	7	8	9	10	11	12	13
Median	7	8	8.5	7	7.5	8	7.5	9	8.5	8	9	8	9
IQR	2.5	2.5	2	2	2.25	3.25	2.25	1	2	2.25	1.25	2.25	1
% agreement	75	75	91.6	83.3	75	58.3	75	83.3	83.3	75	83.3	83.3	100
Round 2: global rating													
Items	1	2	3	4	5	6	7	8	9	10	11	12	13
Median	9	9	8	8	8	9	9	9	8.5	8.5	9	9	9
IQR	1.25	1.25	1.25	1	1	1	1	1	1	1.25	1	1	1
% agreement	91.6	91.6	91.6	91.6	100	100	100	100	100	91.6	100	100	91.6

Item 1: Possible customization by the user; 2: Feedback; 3: rewards; 4:contextualized learning; 5: Enhance motivation; 6: Manage difficulty or complexity; 7: Increasing accessibility:simplicity to use and autonomy; 8: clarity of the instructions or content; 9: Attention capacity; 10: Clear steps or goals for short and long term; 11: Easy to process and modify graphics and audio: keep the environment pleasant but avoid non-essential elements; 12: Human Interaction; 13: Trustworthy.

Table 4
Median of experts' specific rating by ICT for Delphi rounds 1 and 2.

Round 1: specific rating													
Items	1	2	3	4	5	6	7	8	9	10	11	12	13
Robots	8	3	4	7	7	6	6	8	6	5	6	6	7
Serious games & Apps	9	8	9	8	6	9	9	9	9	8	9	9	9
AAC	9	9	9	9	6	4	9	9	9	9	9	9	9
VM	9	6	7	9	8	7	8	9	7	7	9	7	9
Round 2: specific rating													
Items	1	2	3	4	5	6	7	8	9	10	11	12	13
Robots	8	8	8	8	8	8	8	9	8	7	7	8	7
Serious games & Apps	9	9	9	8	9	9	9	9	9	9	9	9	9
AAC	9	9	9	9	9	9	9	9	9	9	9	9	9
VM	9	9	9	8	9	9	9	8	8	8	9	9	9

Item 1: Possible customization by the user; 2: Feedback; 3: rewards; 4: contextualized learning; 5: Enhance motivation; 6: Manage difficulty or complexity; 7: Increasing accessibility:simplicity to use and autonomy; 8: clarity of the instructions or content; 9: Attention capacity; 10: Clear steps or goals for short and long term; 11: Easy to process and modify graphics and audio: keep the environment pleasant but avoid non-essential elements; 12: Human Interaction; 13: Trustworthy.

developers, engineers and users can use the inventory in order to develop tools adapted to people with NDD based on an international consensus and so that should be use in any country. Currently, most of the research in this area does not provide a simple tool that can be easily used to this purpose, whereas people with NDD, their families and professionals are asking for a tool to quickly evaluate if an ICT is adapted to people with NDD (Zervogianni et al., 2020). Some specific tools have been developed for one specific NDD or on specific skills, like reading or social skills, but they cannot be widely used (E.g., Khowaja & Salim, 2020 for vocabulary in children with ASD). Given the high rates of comorbidities between NDD, the use of this inventory should encourage researchers to develop tools adapted to all NDD (Xavier et al., 2020). In addition, most of the design inventories developed targeted one particular type of ICT's such as serious game or robots (e.g., Scassellati et al., 2012 for robots; Whyte et al., 2015 for serious games). This work supports the idea that a design framework can be constructed based on design aspects that are crucial components to consider when working with people with NDD.

The second objective of this inventory is to raise a consensus about which features composed a well-designed ICT for NDD. With a clear consensus, it becomes possible to define the main components an ICT should include. This should help the community in two ways if the inventory is well accepted. First, it should decrease the variability between studies. Currently, the design can widely vary from one tool to another, and it makes the comparison between them hard to make (Grossard et al., 2017). This leads to the second point for which DICTI can be useful, that is the assessment of technologies. The method to assess technologies differs from one paper to another; mostly because the objectives of the studies are defined by the skills they want to work on (i.e. attention, social skills, academic skills …) more than the specific features that should have an ICT (Hollis et al., 2017). Building a tool dedicated to the specific features of ICTs should help clarifying and reducing the heterogeneity in the field. With a better tool to understand the features of ICTs, it offers the possibility to better assess the effect of each of these features. We believe that this type of work will likely improve how we can deal with the question asked by Hollis (2017) and understand what the active components in ICTs are.

4.1. Limitations and future studies

A Delphi study only offers a consensus statement when no or little literature is available (Powell, 2003). In our case, it helps creating and then improving a Design ICT Inventory applicable to all subcategories of ICT that can be used with people with NDD. We contacted experts from different countries who worked on developing ICTs for people with NDD. None of the experts were design engineers despite of having worked with teams who developed or adapted ICT's to this population. We also did not involve peopled with NDD in the panel of experts.

We recruited 12 experts, which correspond to a usual sample size in health-related Delphi study (Trevelyan & Robinson, 2015). However, panels of less than 20 experts may produce unstable findings (Jorm, 2015). In order to compensate this small panel of experts, for the global rating, we used elevated thresholds to ensure that each item was relevant and were able to obtain consensus and agreement for each of them (Von der Gracht, 2012). We made a specific rating by ICT to verify that each item was adapted regarding each ICT. However, we only had three experts for each of the ICT, which does not allow us to rate consensus for each ICT. Moreover, the inventory needs to be validated with proper validation study to calculate interrater agreements in several NDDs and different ICT subcategories. This should be done in future research.

If the DICTI seems relevant to assess the design of an ICT, it is not sufficient in itself to assess the global quality of it. Our inventory is a complementary tool that should be used with other scales and methods that are relevant to create and assess an ICT. Indeed, participatory

Table 5
Final version of the Design ICT Inventory (DICTI).

Features and Targeted Skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
1. Possible customization by the user	0: No personalization	- Customize the characters and the environment	- Appearance of the robots (size, color, form etc.)	- Customized audio and video	- Customized audio and video
	1: Partially considered	- Ability to modify length or order of the exercises	- Characteristics of the robot (gesture, way to control it …)	- Customized messages	- Customized messages
TS: motivation	2: Fully considered	- Different pathways in regard to the user's profile	- Control duration or order of the exercises	- Possibility to arrange the position of the navigation bar	- Ability to select model/actor in video
		- Personalized messages	- Different pathways in regard to the user's profile	- Possibility to select a preferred set of graphic symbols and/or create individualized symbols (i. e. by taking a photo)	
			- Personalized messages		
2. Feedback	0: No feedback	- Specific feedback (i.e. sound or visual bar) when the answer is correct	- Specific feedback (i.e. sound, gestures, body postures, colors) when the answer is correct	- Auditory feedback when choosing symbols	- Opportunity for the user to auto-correct (i.e. including a step to check what was already done)
	1: Feedback but is not clearly related to a goal	- Progression bar/timer	- Each feedback is related to a targeted skill	- Sentence construction: automatic adaptation of grammar and syntax	
TS: identify the targeted task	2: Feedback clearly related to a goal	- Provide visual feedback on progress within the app (i.e. learning map) - Possibility to provide only positive feedback	- Possibility to provide only positive feedback		
3. Rewards	0: No rewards	- Social reinforcement (i. e. applause)	- Social reinforcement (i.e. applause, dance, emotional expressivity)	- Social reinforcement (i.e. at the end of a task in VM)	- Social reinforcement (i.e. at the end of a task in VM)
	1: Social reinforcement (applause) or points only.	- Visual or auditory rewards (video, pictures, songs …)	- Visual or auditory rewards (video, pictures, songs …)	- Visual or auditory rewards (video, pictures, songs …)	- visual or auditory rewards (video, pictures, songs …)
TS: motivation and learning	2: Rewards like objects, videos, song	- Points			
Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
4.Contextualized learning	0: None	- Introduction of real-life scenario	- Scenario must be designed to allow children to draw connections between themselves and their everyday life	- AAC can include video modeling	- Opportunity to create sequences featuring the user as the model (video-self modeling)
	1: Scenario not clearly linked with user's environment	- Downloadable gaming resources	- scenario are associated with everyday life activities to encourage interaction	- technology offers option to select grid-type display or VSD	- Ability to create videos featuring user's actual environment.
TS: generalization and social context	2: Clear link between scenario and user's environment	- choice between first- or third-person view		- Add hotspot to VSD by drawing on the screen	- choice between first- or third-person view
				- available pre-stored vocabulary to illustrate common context	
5. Enhance motivation	0: None	- Includes a companion or enemy in the game	- Robot must be friendly (i.e.: adapted size and appearance) to engage with the children	- Ability to communicate individualized and preferred topics	- Provides encouragement
	1: Partially considered	- Contains jokes or humor	- Provides encouragement (i.e. saying "good job!")	- Integrated a variety of functions of communication (i.e., telephone, play situation …)	- Motivating factors such as humor or encouragement can be added to videos
TS: motivation	2: Fully considered	- Provides encouragement (i.e. saying "good job!")	- being non-judgmental		
6. Manage difficulty or complexity	0: No difference between levels	- The game automatically adapts to the player's performance	- Adapt scaffolding according to scenario and user capacities (i.e. robot can first initiate the interaction, then just support it)	- Choose between different types of symbols (pictures, photographs, traditional orthography/written words) to fit with the level of comprehension of the user	Possibility to see each sequence (video prompting) or all tasks at once (video modeling)
	1: Changes in difficulty without adapting to the player	- Allow the user to adapt manually the difficulty	- Possibility to manage the linguistic difficulty to fit with the user's skills	- Choose between the number of symbols presented in each communication page and in the entire communication book	- Possibility to manage the linguistic difficulty to fit with the user's skills

(*continued on next page*)

Table 5 (*continued*)

Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
TS: accessibility and learning	2: Changes in difficulty in regard to the player (manually or automatically)	- Adapt scaffolding (i.e. provides full support at the beginning of a new task and then diminished it) - Evolving task with increasing difficulty - Possibility to manage the linguistic difficulty to fit with the user's skills - Ability to modify the speed of displaying stimuli	- Ability to modify the speed of displaying stimuli	- Possibility to manage the linguistic difficulty of the vocabulary to fit with the user's skills	- Ability to modify the speed of displaying stimuli
Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
7. Increasing accessibility: simplicity to use and autonomy	0: None	- Simple to use for parents or caregivers (avoids time consuming apps)	- Simple to use for parents or caregivers (avoids time consuming by favoring autonomy of the robots)	- Simple to use for parents or caregivers (avoids time consuming apps)	- Simple to use for parents or caregivers (avoids time consuming apps)
	1: Partially simple (i.e. simple gestures but time consuming)	- Minimizes the number of gestures/click required	- Minimizes the number of gestures required	- Minimizes the number of gestures/click required	- Minimizes the number of gestures/click required
TS: accessibility	2: Easy to use and easily accessible	- Simple actions needed to interact with the support (i.e. keystroke or tapping are easier than drag or swipe)- Easy to use even for non-technologically advanced people - Not related to a specific device or operating system	- Simple actions needed to interact with the robot, adapted to the user - Easy to use even for non-technologically advanced people	- Simple actions needed to interact with the support (i.e. keystroke or tapping are easier than drag or swipe) - Integrate word prediction to support easy access - Easy to use even for non-technologically advanced people - Not related to a specific device or operating system	- Simple actions needed to interact with the support (i.e. keystroke or tapping are easier than drag or swipe)- Easy to use even for non-technologically advanced people - Not related to a specific device or operating system - Can be watched on devices with built in accessibility features
8. Clarity of the instructions and content	0: None	- Contains a tutorial	- Language suitable to developmental age	- Language suitable to developmental age	- Language suitable to developmental age
	1: Language adapted but not visual	- Language suitable to developmental age	- Reminder during task	- Visual symbols easily comprehensive	- Videos are easily understood
TS: accessibility	2: Visual and language adapted	- Visual symbols easily comprehensive - Reminder during tasks	- Robot's actions must be simple and easily understood by the user	- Using animated symbols instead of pictures to help representing actions	- Using videos instead of pictures to help understanding actions
9. Attention capacity	0: None	- Uses stimuli to keep the player engaged	- Adapts the length of tasks depending on the population and scenario	- Allows real time communication (i.e. with pre-registered sentences, prediction of words/ sentences)	- Adapts the length of the video
	1: Adaptation of duration OR stimuli to keep the user engaged	- Adapts the length of tasks	- Uses stimuli to keep the player engaged	- Relieve working memory by keeping the current sentence visible while looking for the next image	- Uses stimuli to keep the user engaged
TS: Attention and fatigability	2: Adaptation of duration AND stimuli to keep the user engaged	- Diminish transition time between games			
Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
10. Clear steps or goals for short and long term	0: None	- Favorized one unique goal per gaming session	- Favorized one unique goal per gaming session when possible, according to the situation	- Clear and simple organization (i.e. clearly identify category inside a folder by provide a	- Each step should be easily identified by the user (i.e.: One video could be related to one step)

(*continued on next page*)

Table 5 (*continued*)

Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
				compilation of images instead of one single related image)	
	1: Limited number of steps/goals in a session OR clear goals	- Differentiation between the immediate goal (goal of a game) and long-term goal (goal of the story)	- Differentiation between the immediate goal (i.e. joint attention) and long-term goal (enhance social skills)	- Thumbnails are clearer than symbols	- Differentiation between the immediate step (i.e. open the fridge) and long-term goal (i.e. make a sandwich)
TS: accessibility and learning	2: Limited number of steps/goals AND clear steps/goals			- Limiting the number steps (i.e. number of location levels)	
11.	0: None	- Avoids non-essential animations to prevent repetitive behaviors	- Avoids non-essential animations to prevent repetitive behaviors	- Has controls for the sounds	- Has controls for the sounds
Easy to process and modify graphics and audio: keep the environment pleasant but avoid non-essential elements	1: Minimalistic graphics OR sounds	- Gives the possibility to customize graphics as character's font or background color	- Has controls for the sounds	- Gives the possibility to customize graphics as character's font or background color	- Control over the video (location, actors, props)
	2: Minimalistic graphics AND sounds	- Gives the possibility to turn off music or sound effects separately	- Animations, sounds and color should be appropriate to the targeted user (in terms of age, skills …)	- Animations, sounds and color should be appropriate to the targeted user (in terms of age, skills …)	- Gives the possibility to customize video elements such as graphics, font or background color
TS: repetitive behavior and attention		- Animations, sounds and color should be appropriate to the targeted user (in terms of age, skills …)			- Animations, sounds and color should be appropriate to the targeted user (in terms of age, skills …)
Features and Targeted skills (TS)	Rating	Serious games and Apps	Robots	AAC	Video Modeling
12. Human interaction	0: None	- Cooperative multiplayer games with caregivers	- Cooperative multiplayer games with caregivers	- Ability to exchange messages with caregivers or family through social media channel and text messaging	- Ability for caregiver or family to create videos
	1: Exchange with one person	- Cooperative multiplayer games with peers	- Cooperative multiplayer games with peers	- Ability to exchange messages with peers through social media channel and text messaging	- Ability for user to exchange videos with peers
TS: social interaction and motivation	2: Multi-users exchange	- Possibility to receive encouragement from family, caregiver, or friends	- support interaction between the user and others according to the user capacity		
13. Trustworthy	0: None	- Assures safety and cybersecurity if needed	- Assures safety and cybersecurity if needed	- Assures safety and cybersecurity if needed	- Assures safety and cybersecurity if needed
	1: Partially considered	- Is robust: avoids bugs and latencies	- Is robust: avoids bugs and latencies	- Is robust: avoids bugs and latencies	- Is robust: avoids bugs and latencies
TS: motivation and accessibility	2: Fully considered	- Clear goals and operation of the device	- Clear goals and operation of the device	- Clear goals and operation of the device	- Clear goals and operation of the device
		- Impact on the user and its environment should be consider (i.e. avoid obsession with the ICT, how to adapt the device to daily life)	- Behavior of the robots must be predictable and understandable to enhance trust	- Impact on the user and its environment should be consider (i.e. how to adapt the device to daily life)	- Impact on the user and its environment should be consider (i.e. how to adapt the device to daily life)
			- Impact on the user and its environment should be consider (i.e. how to adapt the device to daily life)		

design is an important step that is necessary to ensure the ICT is adapted to the targeted population (Frauenberger, 2015). This can be made by consulting users and professionals during the design phase of an ICT through focus group (Tang et al., 2019). Involving both professionals and users is necessary as these groups may differ with regard to the relative importance they placed on varying components of an ICT tool (Parsons & Cobb, 2014). Usability studies are also needed to assess how users interact with the device and are a crucial step to adapt the ICT to the user and their environment (Williams et al., 2006). Finally, strong methodological studies assessing the efficiency and efficacy of ICTs in general are needed. Currently, ICTs appears promising but methodological limitations and small samples sizes do not allow to conclude about their effectiveness (Khan et al., 2019).

5. Conclusion

We constructed the DICTI in order to provide a simple tool to assess the design of current ICTs: robots, serious games and apps, AAC and video modeling. We then conducted a Delphi study in order to validate the items of the inventory. Finally, we obtained a *trans*-technology inventory with 13 items that were validated by 12 international experts. We obtained a quick and easy tool to assess the design of ICTs. Future works should explore psychometric validation of DICTI study (e.g. inter rater reliability). We also think this type of work could be extended to other populations with special needs as well as to the general population.

Authors contributions

Grossard Charline: Investigation, formal analysis, writing. Carlotta Bettancourt & Kellems Ryan: Review & editing. Cohen David & Chetouani Mohamed: Review & editing, Supervision.

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Declaration of competing interest

None.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2022.100261.

* all the papers found in our literature review

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