This book provides an in-depth review of the historical and state-of-the-art use of technology by and for individuals with autism. The design, development, deployment, and evaluation of interactive technologies for use by and with individuals with autism have been rapidly increasing over the last few decades. There is great promise for the use of these technologies to enrich lives, improve the experience of interventions, help with learning, facilitate communication, support data collection, and promote understanding. Emerging technologies in this area also have the potential to enhance assessment and diagnosis of autism, to understand the nature and lived experience of autism, and to help researchers conduct basic and applied research.

The intention of this book is to give readers a comprehensive background for understanding what work has already been completed and its impact as well as what promises and challenges lie ahead. A large majority of existing technologies have been designed for autistic children, there is increased interest in technology's intersection with the lived experiences of autistic adults. By providing a classification scheme and general review, this book can help technology designers, researchers, autistic people, and their advocates better understand how technologies have been successful or unsuccessful, what problems remain open, and where innovations can further address challenges and opportunities for individuals with autism and the variety of stakeholders connected to them.

About SYNTHESIS

This volume is a printed version of a work that appears in the Synthesis Digital Library of Engineering and Computer Science. Synthesis books provide concise, original presentations of important research and development topics, published quickly, in digital and print formats.
Interactive Technologies and Autism
Second Edition
Advances in medicine allow us to live longer, despite the assaults on our bodies from war, environmental damage, and natural disasters. The result is that many of us survive for years or decades with increasing difficulties in tasks such as seeing, hearing, moving, planning, remembering, and communicating.

This series provides current state-of-the-art overviews of key topics in the burgeoning field of assistive technologies. We take a broad view of this field, giving attention not only to prosthetics that compensate for impaired capabilities, but to methods for rehabilitating or restoring function, as well as protective interventions that enable individuals to be healthy for longer periods of time throughout the lifespan. Our emphasis is in the role of information and communications technologies in prosthetics, rehabilitation, and disease prevention.

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SYNTHESIS LECTURES ON ASSISTIVE, REHABILITATIVE, AND HEALTH-PRESERVING TECHNOLOGIES #13
ABSTRACT

This book provides an in-depth review of the historical and state-of-the-art use of technology by and for individuals with autism. The design, development, deployment, and evaluation of interactive technologies for use by and with individuals with autism have been rapidly increasing over the last few decades. There is great promise for the use of these technologies to enrich lives, improve the experience of interventions, help with learning, facilitate communication, support data collection, and promote understanding. Emerging technologies in this area also have the potential to enhance assessment and diagnosis of autism, to understand the nature and lived experience of autism, and to help researchers conduct basic and applied research.

The intention of this book is to give readers a comprehensive background for understanding what work has already been completed and its impact as well as what promises and challenges lie ahead. A large majority of existing technologies have been designed for autistic children, there is increased interest in technology’s intersection with the lived experiences of autistic adults. By providing a classification scheme and general review, this book can help technology designers, researchers, autistic people, and their advocates better understand how technologies have been successful or unsuccessful, what problems remain open, and where innovations can further address challenges and opportunities for individuals with autism and the variety of stakeholders connected to them.

KEYWORDS

autism, autistic, interactive technologies, technology, computing, human-computer interaction, desktop, web, Internet, video, multimedia, mobile, smartphones, tablets, shared active surfaces, tabletop computing, virtual reality, multi-sensory environments, augmented reality, sensors, wearable computing, robots, robotics, natural user interfaces, natural input, pen input, voice input, gestures, speech, tangible computing, tactile computing, eye tracking

1 In this book, we use “people with autism,” “person with autism,” “autistic,” and other terms interchangeably, because there is no agreed upon standard for terminology by the community. We encourage everyone to use whatever labels they prefer for themselves and to request that others respect those labels. We hope our openness to a variety of terminology is seen here as respectful of that agency and self-determination. See Kenny et al. (2016) for more on terminology preferences.
To Maya, Rohan, and Shwetak—J.A.K.

To Warner, William, and Steve—G.R.H.

To Sage, Sophia, and Emmeline—M.S.G.

To Cettina, Pino, and Ajò—M.G.

To Aidan, Blaise, Mary Catherine, Meghan, Sara, and Richard—G.D.A.
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Foreword to the First Edition

This book is a product of pioneering research that the authors, Julie Kientz, Matthew Goodwin, Gillian Hayes, and Gregory Abowd, have conducted—some together in different combinations and some separately—at various research universities such as Georgia Institute of Technology, Massachusetts Institute of Technology, Northeastern University, University of Washington, and University of California, Irvine. The book's immediate impact is two-fold: (1) to demonstrate that interactive technologies are used not only “for,” but also “with” and “by” individuals with autism, and thus to acknowledge their agency, autonomy, and creativity; and (2) to demonstrate that interactive technologies are interactive not only in a dyadic user-technology sense, but also that their use mediates interactions within social networks that include individuals with autism as well as other “stakeholders” in their well-being and participation (i.e., family members, peers, teachers, and practitioners).

The authors' comprehensive review of interactive technologies that have been, and are being created and used, takes stock of the state of technology for autism directed at three areas: enriching interventions, facilitating communication, and supporting data collection. This book expects a significant intellectual investment from its audience. The presentation of content is appropriately complex and does not talk down to the readers. Readers interested in benefiting from this volume will have to inhabit the intricate conceptual universe that the authors have built. In addition to being an invaluable resource for individuals with autism and their families, this book will be useful for researchers and practitioners coming into this very important field.

Olga Solomon, Ph.D.
Division of Occupational Science and Occupational Therapy
University of Southern California
2013
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CHAPTER 1

Introduction

The use of interactive technologies for, by, and in support of people with autism has grown dramatically over the last few decades. Notably, this research is still dominated by a focus on children; however, some recent scholarship has begun to more fully embrace the wide range of experiences of autistic adults. We attempt in this second edition to more explicitly broaden this review and call out those challenges. Some people claim that autistic people show particular interest in interactive technologies, particularly when they are made inclusive and accessible (Mazurek et al., 2012). During the last two decades, however, use of a variety of personal, social, and organizational technologies has simply become commonplace for all people. This review, then, does not attempt a comprehensive examination of technology use by people with autism and related conditions. Rather, the following pages are dedicated to a consideration of the empirical and published research focused on use of interactive technologies to support and enhance clinical and therapeutic goals for screening and diagnosis, educational goals for intervention monitoring, and other research efforts in support of this community. We take note, when and where possible, of existing gaps we identify in the literature, such as the focus on children noted above or the limited research published by people with autism about their own communities.

This second edition of this book comes nearly a decade after the first version. Our intention then, as now, is to help readers understand some basics of autism and then provide a broad review of the research literature that demonstrates the role technology has served, with some hints to roles it might serve in the future. We note, however, that none of the authors of this book themselves identify as autistic, though we are variably parents, siblings, friends, cousins, and caregivers of people with autism from infant to adult. This book, therefore, is drafted with some level of third-party distance but caring hearts and open minds and a healthy dose of chagrin. In particular, in this second edition, we have made an explicit point to gain feedback from and reviews by people with autism and related conditions.

We expect this book can be useful to new researchers to the area of autism and technology as well as more experienced researchers who are looking to identify new potential areas of focus. We also expect this may be useful to employers, teachers, parents, caregivers, friends, children, and autistic people who want to know more about the research surrounding interactive technology use for autism. We recommend greater discussions with a variety of community groups for those who want to better understand the lived experience of use of these technologies beyond what is represented explicitly in the research literature we cover here. We aim to identify problems that still need to be solved and suggest promising avenues for further development and evaluation, all in service
of advancing science, technology, and quality of life for individuals with autism. We also hope to encourage more research in this space, as there are many interactive technologies that are being used for autism that show much promise but have not yet been scientifically validated.

1.1 INTRODUCTION TO AUTISM

Autism was first described as a syndrome by Leo Kanner, a child psychiatrist at John Hopkins University (Kanner, 1943). In his seminal work, Kanner characterized 11 children who shared what he understood to be a fundamental inability to relate to other people, a failure to use language to convey meaning, and an almost obsessive desire to maintain sameness. Our understanding of these “symptoms” has, of course, evolved over time, and we would never recommend using this kind of deficit-based language to describe autism in a modern context. Kanner also noted that anxiety played a prominent role in the clinical presentation of autism; the children he observed often displayed intense fears of common objects. Bettelheim (1967) suggested autism was the result of inadequate nurturing by emotionally cold, rejecting parents, a theory that prevailed until the late 1960s and did a great deal of harm to many families. Rimland (1964) and Rutter (1970) provided persuasive arguments that autism had an organic etiology, the most influential of their findings being that approximately 25% of children with autism developed seizures in adolescence. Current science is in substantial agreement that autism is a complex neurodevelopmental condition with underlying organic genetic and neurological differences, and it is not caused by parenting deficiencies or other social factors. However, some debate continues to exist around epigenetic phenomenon, environmental triggers and contexts, and the cultural creation of types of autism and autistic symptomology. Autism occurs across all socioeconomic levels, in all cultures, and in all racial and ethnic groups (Dyches, Wilder, and Obiakor, 2001). Furthermore, autism is not necessarily debilitating, and autistic people often live happy, full, fruitful lives in a wide variety of contexts. Being autistic, just like being tall or a woman or having brown hair, can be beautiful and wonderful in accepting and accessible societies. It can also be challenging and difficult, particularly for people who experience other co-occurring disabilities or who must live and work in inaccessible contexts.

There is no specific biomarker, laboratory test, or behavioral assessment procedure to identify autism; it is defined exclusively by past and present behavior determined from developmental history interviews (e.g., Autism Diagnostic Interview), parent reporting on current behavior (e.g., Modified Checklist for Autism in Toddlers), and structured and semi-structured tasks that involve social interaction between an examiner and a person being diagnosed (e.g., Autism Diagnostic Observation Schedule). Most people in research studies are children, which can contribute to the idea that all people with autism are children or child-like. This infantilization—even when implicit, explicit, or accidental—can be of great harm to adults with autism and must be addressed in future research. As the increasing number of children diagnosed with autism age into adulthood, and more
adults seek diagnoses later in life, this expanded view of autism that includes highly successful adults must also be considered, something that is a relatively large gap in current research.

Autism is a spectrum condition covering a wide range of ability levels and encompassing a diverse set of symptoms, ranging from more severely affected to what many references as high functioning (often referred to as high-functioning autism or HFA). Despite this heterogeneity, all individuals on the autism spectrum are characterized by qualitative (i.e., exceptional and not merely delayed development) impairments in social-communication and restricted and repetitive interests, activities, and behavior (see DSM-5, American Psychiatric Association, 2013). We note that the DSM-IV (American Psychiatric Association, 2000) included Asperger’s Syndrome as part of Autism Spectrum Disorders. The DSM-V, introduced in 2013, has removed that sub-classification. A number of the articles reviewed in this book were designed for or tested with individuals with Asperger’s Syndrome as defined by the DSM-IV. The DSM-IV diagnosis also classified other disorders as Autism Spectrum Disorders, such as Childhood Disintegrative Disorder, Rett’s Disorder, and Pervasive Developmental Disorders-Not Otherwise Specified, which have also been removed from the DSM-V criteria. There has been some amount of controversy surrounding the new diagnostic criteria, and not everyone agrees. For the purposes of this review, we make use of the diagnostic category in common use at the time the research was conducted. However, outside of a formal research review, we recommend deferring to those titles and labels that autistic people themselves prefer when they are able to state a preference and that their friends and family closest to them prefer when they are not.

Autism is more commonly diagnosed in genetic males than females, with a ratio of 4:1 widely reported across samples (e.g., Fombonne, 2002). Many individuals with autism, but not all, also have moderate to severe cognitive impairments (Fombonne, 1999); suffer from seizures, with onset most often occurring during either the preschool or adolescent years (Volkmar and Nelson, 1990); and/or experience co-occurring neurodevelopmental conditions, for example, Tourette syndrome (Sverd, Montero, and Gurevich, 1993) and attention deficit hyperactivity disorder (ADHD) (Ghaziuddin, Tsai, and Ghaziuddin, 1992).

Early research suggested that autism was originally considered relatively rare, occurring at a rate of 4 to 6 affected individuals per 10,000 (Lotter, 1967; Wing and Gould, 1979). In the mid-1980s, diagnostic criteria broadened, and rates of 10 per 10,000 were found in total population screenings (Bryson, Clark, and Smith, 1988). More recent studies that focus on preschool children utilize standardized diagnostic measures of established reliability and validity, employ active ascertainment techniques, and yield prevalence estimates of 60–70 per 10,000—translating into approximately 1 in 150 across the spectrum of autism (Baird et al., 2001; Bertrand et al., 2001; Chakrabarti and Fombonne, 2001). At the time of writing, the most recent estimates from the Centers for Disease Control and Prevention (CDC) suggest a rate of 1 in 59 children (Baio et al.,

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1 For a caveat to these estimates, see Mottron et al. (2006).
1. INTRODUCTION

2018) but do not state a prevalence rate for adults. Another study reported that 1 in 50 students in U.S. schools receive services related to autism (Blumberg et al., 2013), although no independent replications have confirmed this prevalence estimate. Regardless of the true rate of autism, more than 2 million people in the U.S. are currently believed to carry the diagnosis.

This apparent increase has led to dramatic claims, particularly in the popular media, for an “epidemic” of autism. However, according to reviews by Wing and Potter (2002), Rutter (2005), and Gernsbacher and colleagues (2005), there are several possible reasons for the observed increase in autism rates, including: (1) changes in diagnostic practice; (2) increased awareness among parents, professionals, adults with autism themselves, and the general public of the existence of autism; (3) development of specialist services; (4) differences in methods used in studies; and (5) a possible true increase in numbers.

Individuals with autism often encounter challenges across the entire range of developmental milestones and areas. Of course, development is traditionally thought of as primarily child development, but autism, as a lifelong condition, must consider other aspects of human development and developmental milestones later in life. These might include milestones like entering and exiting child-bearing years, other physical changes surrounding aging, and changes in our socio-emotional development such as through work and interpersonal relationships. The unfolding and maturation of developmental competencies are affected to a greater or lesser degree in autism, depending on each individual’s pattern of behaviors, extent of impairment in relation to their environment, and level of support. Autism is almost always a chronic condition; however, the abilities and challenges of individuals is not static. Just as other people do, individuals with autism continue to grow, learn, and develop over the course of their lives. While there is great variability across the autism spectrum, and individual differences make it difficult to generalize across the condition, some general patterns of development can be offered as children with autism move from infancy through adolescence, adulthood, and beyond.

Autism, as with other complex conditions, typically manifests quite differently across people who share the same diagnostic label. Moreover, autism may even present itself differently in the same person across settings and over time. This extreme heterogeneity among the autistic community has led to the common colloquial saying, “If you’ve seen one person with autism, you’ve seen one person with autism.” However, there are some commonalities, which we describe in the subsequent sections, particularly as they relate access to and use of technology.

1.1.1 INFANT DEVELOPMENT

Infancy is a period of dynamic growth and change. During this time, early symptoms of autism are found to cluster around impairments in early emerging social interaction skills, including attentional functioning, preverbal communication, exploration and play, motor imitation, and at-
attachment. One of the important aspects of attention is the ability to identify and focus on salient elements or features in the environment for further processing (James, 1950). In the first year of life, infants with autism are typically found to visually orient less frequently to people as compared to typical and developmentally delayed infants (Osterling, Dawson, and Munson, 2002). This selective bias is found to persist in the second year and beyond (Dawson et al., 1998). More recent findings suggest this pattern of attention in the first year of life may serve as an effective diagnostic criterion for autism (Klin et al., 2009).

In the first nine months of typical development, and before the development of speech, infants are able to effectively communicate their needs by a variety of means, including reaching for a desired object, fussing, or crying. These communicative attempts are usually directed at the goal itself and not at the person that might be instrumental in attaining the goal. At about nine months, infants begin to direct their communicative attempts toward adults by, for instance, making eye contact while reaching for a distant toy. Along with this change, infants begin to substitute early emerging physical gestures (e.g., an open-hand reach) with conventional gestures such as pointing or showing. Emergence of these behaviors at the end of the first year of life marks the beginnings of intentional communication—communication in which a child is aware that his or her behavior affects a listener (Bates, 1979).

Pre-verbal children with autism typically communicate less frequently (Stone et al., 1997) and use less complex combinations of communicative nonverbal behaviors (Stone et al., 1997). Specifically, two-year-old children with autism are less likely to use eye contact or conventional gestures, such as distal and proximal pointing and showing gestures. They are more likely to manipulate a person’s hand using hand-over-hand gestures and are less likely to pair their communicative gestures with eye contact and vocalizations compared to developmentally typical peers (Stone et al., 1997). A disproportionately high number of the communicative behaviors observed in young children with autism are also concerned with requesting objects or actions rather than directing another’s attention to an object or event to initiate joint attention (Baron-Cohen, 1989; Bruner, 1975; Mundy and Sigman, 1989). Compared to typically developing peers, most autistic children also develop language later, and their language development is marked by the presence of unusual features (Tager-Flusberg, Lord, and Paul, 2005). For instance, pre-verbal children with autism often show atypical patterns of sound production, including imperfections in well-formed syllables and overproduction of atypical vocalizations such as growling, tongue clicking, and trills (Wetherby, Yonclas, and Bryan, 1989).

Differences in functional and symbolic play in relation to other cognitive skills have also been well documented in autistic preschool children (Sigman and Ruskin, 1999). While play skills continue to develop in the preschool period and can be enhanced through prompts, scaffolding, and modeling, children with autism tend to engage in little spontaneous functional and pretend play at this age (Lewis and Boucher, 1988).
Motor imitation and emulation also play an important role in the emergence of both symbolic and social-cognitive skills (Tomasello, Kruger, and Ratner, 1993). Studies on imitation in autistic preschool children consistently report significant differences in this area (e.g., Rogers, 1999). There has been some speculation that attachment, the affective bond between a child and a parental figure (Ainsworth et al., 1978), is deficient in infants with autism, but there is little evidence to support this claim (Capps, Sigman, and Mundy, 1994). And indeed, such assertions can be considered offensive in much the same way as the early “cold mother” ideas about causes of autism. Other impacts of autism on daily life are detailed in later chapters when relevant to the design of specific technologies.

1.1.2 EARLY CHILDHOOD AND SCHOOL-AGE CHILDREN

The developmental characteristics of autism in infancy tend to persist over time. In school-aged children, these characteristics manifest in specific cognitive, behavioral, communication, and social profiles.

Elementary or primary school years bring challenges associated with changing expectations that accompany increasing physical and behavioral maturity. During the period from ages 6–12, children must transition to new learning environments, develop more sustained contact with new peers and adults, and experience a departure from familiar places and routines. These changes can affect many behaviors in all children, as the child is required to adapt to more complex and demanding social environments, learn more sophisticated skills, communicate at a higher level, and process more information. Such experiences, which are common to all school-aged children, can create substantial barriers for those with autism, who sometimes have developmental delays in multiple domains and/or difficulty adjusting to changes in their environments.

Although there is considerable heterogeneity among children with autism, some generalizations can be made. For example, Wing and colleagues have described three subtypes of social behavior—aloof, passive, and active-but-odd—that capture many of the manifestations of autism seen in the school-age child (Wing and Attwood, 1987; Wing and Gould, 1979). While these labels are offensive when viewed through today’s more inclusive approach, they were groundbreaking in the 1970s. They remain useful categories if not useful labels.

The aloof profile is most likely to be described as “classically autistic.” These children do not seek, and may actively avoid, contact with others and may become very distressed if forced to do so. Despite having verbal abilities, they do not initiate communication, and much of their time may be occupied with stereotyped or other repetitive interests. These children with autism are noted for their unresponsiveness and lack of attempts to initiate interactions with both peers and adults. They often do not play with other children or demonstrate interest in friendships (Rutter, 1974). Impairments in their ability to use eye gaze and gesture appropriately in social situations lead to
frequent communication difficulties. “Aloof” children may also be sufficiently unresponsive, making it very difficult to direct and maintain their attention. They may seem deaf at times, even though they are not. Meltdowns are common in these children, particularly when their routine is disrupted or by other circumstances they cannot control. While individuals with these characteristics are most often seen in the preschool age group, some continue in this manner into later childhood, adolescence, and adulthood. Older individuals with this profile are most likely to have severe cognitive impairments (Seltzer et al., 2004).

The passive group includes children who do not actively avoid social contact with others, but who nevertheless lack the spontaneous and intuitive grasp of social interaction achieved in normally developing children. They may accept social approaches of others, but often do not have the skills or interest to respond in a way that other children might read as appropriate. Their communication and play behaviors can be more rigid than typically developing peers and sometimes stereotyped. These individuals tend to test higher in terms of language and motor skills than those in the aloof group. Although “passive” children can be easier to engage and support than those who are aloof, they often still require considerable help relating to peers in the classroom or other situations. Some children with autism who start out displaying the aloof pattern of behavior later have a better fit with the passive group. Thus, presentation as aloof versus passive may depend to some extent on the child’s developmental level, and a transition from one category to the other may reflect maturation, effective interventions, and/or accumulation of social experiences.

The active-but-odd children are those who are usually described currently as having “higher functioning” autism or may not even identify as having an autism diagnosis at all. They actively seek contact with others, but the form and quality of their social approaches are atypical and may sometimes be read as inappropriate by adults or typically developing peers. These people experience difficulty relating socially to peers, even though they may have considerable language skills and may be interested in communicating with others. Behaviors common to this group include repetitive questioning, inappropriate touching, conversations focused exclusively on the child’s own narrow interests, and unexpected facial expressions, postures, and gestures. Their social behavior and communication seem to reflect a view of the social world that is literal and concrete, and they can show limited awareness of the feelings, thoughts, and motives of others.

1.1.3 ADOLESCENCE

The clinical presentation of adolescents with autism has not yet been studied as extensively as younger children with autism, and self-identification has been studied even less. Very few studies have examined whether contextual variables such as parental socio-emotional functioning, place of residence, and educational or intervention history predict later outcomes. However, the limited research suggests that adolescents with autism can follow any of three paths: change their behavior
dramatically, experience deterioration in their ability to successfully navigate the social world, or continue a stable maturational course (Seltzer et al., 2004). A key variable mediating these developmental trajectories appears to be intellectual ability. Individuals with autism and intellectual disability (defined by an IQ of less than 70, though it is often difficult for IQ to be measured in autistic people, whether children or adults) have significantly greater difficulties in terms of education, work, living situation, and general independence than those with autism and average intelligence (Howlin et al., 2004). Many parents also report that their intellectually disabled adolescent with autism exhibits significant behavior problems, including resistance to change, compulsions, inappropriate sexual behavior, meltdowns, aggression, and self-injurious behavior (DeMyer, 1979).

Some researchers have begun to examine specific patterns observed in adolescences, such as differences in motivation (e.g., Bos et al., 2019). Likewise, friendship, so important in adolescence for most people, has emerged as an area of focus for autism researchers worldwide (e.g., Chang et al., 2019).

For higher functioning adolescents with autism, academic performance can be at or above grade level; however, organizational and social expectations (e.g., keeping track of multiple assignments and long-term projects; moving quickly between classes; avoiding social taboos) can be overwhelming (Klin and Volkmar, 2000). For those with typical or high intelligence levels who identify as being on the autism spectrum, adolescence may also be a time of heightened loneliness, anxiety, and depression as they recognize the profound nature of their difficulties, their differences from others, and their limited opportunities (Green et al., 2000).

1.1.4 ADULTS WITH AUTISM

Unfortunately, very little is currently known about the ways autism manifests in adulthood and how best to support this older segment of the autism population. A potentially worrisome trend, in fact, is the ending of many longitudinal studies in adolescence rather than adulthood (e.g., Ben-Itzchak and Zachor, 2019; Lin et al., 2019). Lifetime longitudinal studies are incredibly expensive and difficult to undertake, but given the paucity of research on adults, it may be worth the investment. In general, the autistic adult experience is a great area for future research, as the adult population of individuals living with autism will be greatly increasing as the increase in the diagnosis of children increases and these children become adults. Studies that have begun to emerge can focus on issues like anxiety and depression that pervade a lifetime (e.g., Uljarevic et al., 2019, Gillan, 2019) or on specific concerns of adults with autism (e.g. sexuality (Parchomiuk, 2019)). There have been some promising studies with adults in the workplace (e.g., Hendricks, 2010; Hedley et al., 2017; Annabi and Locke, 2019; Wills et al., 2019) as well as increasing initiatives in a variety of corporations and non-profits to develop neurodiverse workforces. Likewise, increasing efforts have sought to include
autistic adults in the design process, such as the Clap novel tactile anxiety management program (Simm et al., 2014).

1.1.5 THE ROLE OF SOCIAL ENVIRONMENT

A transactional model of development recognizes the individual as an active participant in the developmental process who, through continued and varied interactions with the environment, comes to adapt, learn, and develop (Bronfenbrenner, 1979). In addition to the individual-level characteristics of autism described above, there are also factors relating to the family and school environment that contribute to developmental outcomes in this population. The following briefly reviews the roles that families and schools play in autism.

Questions about interactions between family context and the developmental trajectory of autism are relatively understudied. Studies in autism have focused primarily on child variables and child outcomes or on the stress of life for parents. Family variables, considered to be critical to general early intervention research (such as socioeconomic status, stress, supports available, and parents’ involvement in a child’s development), have not been well addressed in outcome studies (Gresham and MacMillan, 1997). However, there are a few studies showing that family involvement in intervention is a strong predictor of outcome in children with autism (Dawson and Osterling, 1997; Dunlap, 1999; Lord and McGee, 2001; Rogers, 1998). Family influences on adults have not been covered in the research literature and are an important area of future research. Conversely, borrowing from the broader developmental literature, negative family factors including limited financial resources, lack of appropriate services, and insufficient support systems most likely produce unfavorable prognoses in children with autism. Environmental risk factors, such as lack of services and negative attitudes toward disability, probably also negatively influence the development of a child with autism as well as concerns of adults, such as barriers to employment and post-secondary education. However, as mentioned previously, there is very little systematic investigation of these factors in autism, particularly beyond early childhood.

Research also suggests that school-based interventions that utilize a structured environment and intensive early behavioral, language, and social skills training (Rogers, 2000; Smith, Groen, and Wynn, 2000) can be effective in helping children with autism. Structure helps students with autism by making elements of the learning environment clearer and more predictable (Olley, 2005). Individualized interventions and education goals that are developmentally appropriate have also been shown to address this population’s abilities and impairments and facilitate development (Schreibman and Ingersoll, 2005). These same kind of highly structured approaches have begun to be explored for adults who identify as autistic as well in learning (e.g., Duggal et al., 2019) and workplace contexts (e.g., Wills et al., 2019).
1.1.6 MOVING TOWARD ACCEPTANCE AND INCLUSION

The medical model of disability most often invoked—sometimes unintentionally—in the work we review focuses on physical and functional limitations a person might exhibit, and thereby looks to augment, assist, or adjust for these deficiencies. Other approaches include a social model that focuses on condition management and independent living, rather than “fixing” a person with a disability (Zola, 1983), as well as post-modern approaches that privilege each unique individual’s lived experience (Pinder, 1996). There is increasing movement toward these models of acceptance and inclusion that both address the unique needs of individuals with autism as well as the social and structural barriers present in their lived experience. Research has also focused on describing the relationship between assistive technologies and disability studies (Mankoff et al., 2010), as well as consideration of neurodiversity in human–computer interaction research (Dalton, 2013). One promising area of future research is to identify how some of the technologies reviewed in this article might be re-envisioned to support more of a social acceptance and inclusive perspective rather than one focusing on rehabilitation, such as pioneering work in the education space on inclusive education (Odom and Diamond, 1998), building on pioneering work on re-visioning technologies and design methods to focus on inclusion and engage directly with individuals with autism (e.g., Sobel et al., 2015; Spiel et al., 2017). Similarly, Milton (2012) describes the “double empathy problem” in an attempt to move away from autism being defined as a deficit of some sort, frequently in theory of mind, but instead being a difference in reciprocity and mutuality.

1.1.7 ADDITIONAL CHALLENGES WITH AUTISM

Research evidence in the behavioral, educational, and social sciences indicates that early diagnosis and intervention can be essential to achieving greater independence. Over the last two decades, popular press and parenting forums have taken this advice to heart, pushing parents and teachers to act more and more quickly. Thus, caregivers can feel that they are in a race against time to find interventions that work for their child. However, many interventions may or may not work for any particular child, and these interventions are often applied simultaneously. Interventions commonly take the form of pharmacology, special diets, occupational therapy and sensory integration, behavioral therapies such as applied behavior analysis or functional behavior analysis, and symptom-specific support such as speech or language therapy. It may also be the case that the predominant push to conduct research with autistic children rather than adults has been created in part by this emphasis on “early intervention.”

The difficulty obtaining an early diagnosis, inherent heterogeneity in clinical presentation, and lack of a complete evidence-based research on the effectiveness of interventions all present significant challenges to those who support individuals with autism. While the condition has been known in the literature since the 1940s, we are increasingly learning how complex a condition
autism is and how its etiology is at best a complex combination of genetic predisposition and environmental hazards. Despite our incomplete knowledge, there is still a lot we do understand about the challenges of autism in everyday life, and hence a lot that can be done to address them.

1.2 COMPUTER USE BY INDIVIDUALS WITH AUTISM

It is widely accepted that computing applications in multiple domains are largely successful when used by people who identify as autistic. Compared to the accessibility challenges seen with physical disabilities (e.g., blindness or paralysis) or with other cognitive differences (e.g., related to aging and dementia), autism is somewhat unique in that most computing interfaces mostly work for autistic people. The earliest articles we are aware of that discuss the use of computers and why they are promising for individuals with autism is that of Colby and colleagues (Colby, 1973; Colby and Smith, 1971). Another early work was the use of a microprocessor-based system for training individuals with autism using prompting and data collection (Rathkey et al., 1979). Panyan (1984) suggested that computer use in autism could increase learning rates, ability to work independently, creativity, and attention and social behaviors. More recently, Silver and Oakes (2001) outlined several factors that may help explain the particular affinity for computers observed in individuals with autism. First, individuals with autism often have difficulty filtering sensory information that is not salient to their daily interactions (Rutter and Schopler, 1987). Computer screens allow information to be abstracted or limited to only relevant information, thereby supporting the filtering process. Second, many individuals with autism are often confused by unpredictability, social nuance, and rapid changes present in the non-computerized physical world. Computers are much more predictable than humans and do not require social interactions. Additionally, computational interactions can be repeated indefinitely until the individual achieves mastery. Third, computers can provide routines that are explicit, have clear expectations, and deliver consistent rewards or consequences for responses, which can encourage engagement with educational and assistive technologies by allowing an individual to make choices and take control over their pace of learning. Fourth, content can be selected and matched to an individual’s cognitive ability and made relevant to their current environment, and photos can be used to help generalize to the real world. Finally, learning experiences can be broken down into small and logical steps and progress at a rate necessary for conditioned reinforcement. The data collected by computers can also be useful for assessing progress in learning, self-monitoring, and adaptive uses to support employment, greater autonomy, and postsecondary education.

In general, due to the individualistic nature of the autism experience, computer-based interventions can be tailored to an individual’s needs or even special interests (Morris et al., 2010), which can potentially enhance learning and maintain interest over time. Because of these perceived benefits of using computers, they have become an integral part of a number of interventions and
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Educational programs. They have also become a good way of supplementing face-to-face therapies that are time, cost, and/or other-resource prohibitive.

A number of approaches to designing interactive technologies for individuals with autism have been proposed. Lahm (1996) conducted a study assessing software features and what engages individuals with autism in the classroom and found that technology with higher interaction requirements and those that use animation, sound, and voice were more likely to captivate attention. Several papers discuss the experience of using participatory design with children with special needs (Benton et al. 2012; Frauenberger et al., 2011, 2012; Constantin et al., 2019) and more specifically children (Millen et al., 2011; Ghanouni et al., 2019b) and adolescents with autism (Madsen et al., 2009a; Zhu et al., 2019). Navedo et al. (2019) explicitly called out a strengths-based approach for such design. Kaufman and colleagues (2011) describe their experience with iterative design for advancing the science of autism, and Porayska-Pomsta and colleagues (2012) discussed an interdisciplinary approach to technology design for individuals with autism. Finally, Putnam and Chong (2008) conducted a survey with parents of individuals with autism to understand what needs they have in computing software and found that social skills, academic skills, and organization skills were the most important areas for interactive technologies.

1.3 OTHER REVIEW ARTICLES

This book is not the first to review the space of autism and technology. In our literature review, we encountered a number of summary articles, ranging from systematic and meta-analytic reviews (e.g., Ramdoss et al., 2011; Grynszpan et al., 2013) to discussion or thought pieces about the future of technology in support of autism (e.g., Goldsmith and LeBlanc, 2004). We also encountered many articles that sought to review specific types of technologies for use with individuals with autism, such as robotics (e.g., Feil-Seifer and Matarić, 2009), virtual reality (e.g., Parsons and Mitchell, 2002), tabletops (e.g., Piper et al., 2006), video instruction (e.g., Ayres and Langone, 2005a), pervasive computing (e.g., Kientz et al., 2007), speech output (e.g., Schlosser and Blischak, 2001), and computer-mediated communication (e.g., Burke et al., 2010). In addition, we encountered a number of articles that describe the use of technologies for specific purposes, such as communication (e.g., Mirenda, 2001), functional skills instruction (e.g., Ayres and Langone, 2005b), and social skills (e.g., Reed et al., 2011; Wainer and Ingersoll, 2011). There have also been review articles that discuss the role of technology in supporting family and caregivers of individuals with autism (e.g., Oberleitner et al., 2006; Solomon, 2012). Spiel et al. (2019) brought important voice to these discussions with their critical literature review in 2019, including critiques directed at the first edition of this book, which we have taken to heart and incorporated as much as possible. Finally, important discussions are taking place about mapping a research agenda for autism and technology research that incorporates all stakeholders (Parsons et al., 2020). They propose a framework for
future research that focuses on social inclusion, perspectives, participation, and agency, suggesting that research focusing on autism as a “disorder” to be addressed is exclusionary and that an agenda promoting diversity, inclusion, and equity and engages the voices of autistic individuals is the future of research in this space.

In this book, we make no attempt to include every article written on the subject of technology and autism. Indeed, over the course of writing this book, and in the 10 years between the first and second editions, many more relevant articles came to our attention, a testament to the promise and interest in this rapidly growing area. Thus, we focus here on providing a classification scheme from which to overview the general space that is beneficial to those seeking a basic introduction to the area, while providing enough detail to foster future research and allow current researchers to position their work among existing literature. We encourage readers to characterize their own work using our provided classification scheme, discussed in Chapter 2. In the current review, we also largely leave the kind of critique of technologies that one might invoke based on different models of disability to the side in favor of a broader summarization of technological approaches.

1.4 STRUCTURE OF THIS REVIEW

The structure of this review is as follows. We first begin with a discussion of our method for identifying published papers included in this review and provide a description of the classification scheme we developed for organizing different technologies according to input and output types, domain, goal, target end user, setting, publication venue, empirical support, technological maturity, and engagement of individuals with autism. The next seven chapters constitute the core of our review and are based on seven general types of interactive technology platforms, including personal computers and use of the Web, mobile devices, shared active surfaces, virtual and augmented reality, sensor and wearable technologies, robotics, and natural user interfaces. In each core review chapter, we review technologies that use the platform and provide a discussion of challenges and future directions for research using that platform. We conclude the book with some overall discussion points and thoughts for the future of interactive technologies for autism.
In this chapter, we provide a description of the methods we used to identify and classify interactive technology research included in this review. Through a high-level analysis of the existing literature, we developed a classification scheme to help categorize each technology approach. Several frameworks could be developed around the same body of literature, and in fact, we experimented with multiple approaches while drafting this content for the first edition. Ultimately, we settled on an approach that is both descriptive and explanatory, while supporting the potential for exploration and innovation going forward. This classification scheme has also evolved over the years as new technology platforms and applications are explored. For the second edition, for example, virtual reality had greatly expanded in the intervening decade.

2.1 METHODS

This section is intended to provide an overview of the use of interactive technologies by and for autistic people—including those with childhood diagnoses, those with adult diagnoses, and those who may be undiagnosed but nevertheless identify as being on the autism spectrum—as well as for researchers new to the area, who may already be experts in a variety of social, medical, and computer science fields, or who may be new to research altogether. Given the rapid growth rate in this field, we did not set out to conduct a comprehensive review of the literature. Rather, with a focus on being as inclusive as possible, we set out to understand both the research and design spaces of this important and continually growing field. Notably, there are a wide variety of relevant commercial products in this space as well. Given our focus on research and the difficulty of conducting any type of comprehensive review of commercially available products, we limit our discussion primarily to research projects and research-validated products but do include commercial products when they are particularly relevant. As a result of this approach, we did not have specific inclusion and exclusion criteria for works included in this review. Others have conducted systematic reviews and meta-analyses of the autism and technology literature that we defer to for this level of analysis (Ramdoss et al., 2011; Grynszpan et al., 2013).

In gathering papers to include in this review, we conducted searches on the ACM Digital Library, IEEE Xplore, PubMed, ERIC, and PsychInfo. We also searched abstracts of the International Society for Autism Research (INSAR) from the last five years on Google Scholar to identify published papers from those projects. Keywords included “Autism,” “Asperger,” “PDD-NOS,” “Technology,” “Computer,” “Robot,” “Sensor,” “Virtual Reality,” and “Mobile.” We then searched
citations of the resulting articles for additional papers to include. From the resulting papers, we narrowed down the list to those that fit our definition of interactive technologies and included the most recent articles for each application identified. We included technologies that ranged from demos to fully functional or publicly available technologies and those that have been used by, or specifically designed for, individuals with autism and their caregivers. We did not include technologies that had the potential to be used for autism but had not yet been applied to this domain. We note that there may be additional and related search terms beyond those identified, and while we tried to be as inclusive as possible, the search we conducted was not intended to be systematic. The review we conducted was first done in 2013 when the first version of this book was published, and then again in 2019 for the second edition.

Our review and classification scheme are based on technologies described specifically in the papers we identified, as opposed to hypothetical or extrapolated uses, such as those mentioned in a critical review intro or discussed in conclusion/future directions section or based on what we know from outside knowledge or future work. We focused our search on those technologies that originated from the research community or have a basis in research-validated intervention techniques. This ended up excluding a number of applications from popular media, such as games for children with autism found in the Apple App Store\(^2\) or on Google Play.\(^3\) These marketplaces are rich with different applications, but in general, they are beyond the scope of this book unless they have been studied in the scientific literature.

### 2.2 CLASSIFICATION SCHEME

To organize the papers, we conducted bottom-up coding of different aspects of 26 influential papers across a broad spectrum in the area of technology and autism to determine a set of characteristics that define their use, listed in Figure 2.1. To refine the codes further, we individually applied these codes to a larger set of papers, and then met to discuss the application of the codes and finalize the set. Once there was strong agreement among the authors, we categorized the codes and wrote definitions to develop a classification scheme to help organize existing literature and projects relating to interactive technologies for autism and to help identify areas for future work. This process was repeated and refined for the second edition of this book.

The first edition of this book focused its bottom-up review on 20 papers, and the revision of this book removed some papers and added others that were more relevant, for a total of 26. The original classification scheme from the first edition of the book consisted of eight dimensions, and the final scheme for this latest edition consists of 10 different dimensions along which projects can be categorized. In particular, we decided that the “technology platform” classification scheme did


\(^3\) [http://play.google.com/store](http://play.google.com/store)
not reflect the changing nature of technology as well, and thus we replaced it with input and output modalities and only used technology platform as an organizing scheme for chapters. In addition, the shift of research in this space from being designed in service of people with autism to be more about designing with autistic people necessitated the inclusion of a classification scheme for how people with autism were included in the technology design process. This shift hopefully provides additional considerations for the agency of all people with autism, though particularly for autistic adults and those who identify as being on the autism spectrum. Finally, we made minor updates within some of the other dimensions to reflect changes in terminology or to collapse or separate sub-dimensions.

Within each dimension, we determined several labels that could describe the work either based on prior literature or on our own initial coding. Below, we list the 11 dimensions, along with associated labels within those dimensions and their operational definitions. For each technology, it is possible that several labels exist within each dimension, such as a technology being used for both home and school settings or one that is used by both individuals with autism and their family members.

2.2.1 INPUT MODALITY

One of the ways that interactive technologies are defined is by their input and output modalities. This is the channel by which interactions from a person are transmitted to a computing system (Karray et al., 2008). Systems might be considered unimodal or multimodal if they engage one or more input types respectively. This section describes the different input types that interactive technology may have, meaning how the user gives information to the technology. Input may be captured via a number of methods, including direct connections to the computing device, sensors, computer vision, microphones, etc.

- **Audio**: Any speech or non-speech audio-based input, such as spoken voice dictation, natural speech processing, audio-command input, or non-speech audio input such as humming or snapping fingers.

- **Physical**: Includes any methods that require the user to physically touch something, including touchscreens, keyboards, pointing devices (e.g., mouse, trackball, etc.), video game controllers, buttons, switches, etc.

- **Spatial**: Any input based on movement within a space, including based on gestures, body movement (e.g., accelerometers or eye tracking), orientation, or location-based tracking such as with GPS or indoor localization.
2. METHODS AND CLASSIFICATION SCHEME

2.2.2 OUTPUT MODALITY

Output modalities are ways in which a computing system provides information that can be perceived by the user. These are largely based on the five senses of humans and what they are able to perceive.

- **Audio**: Any speech or non-speech output perceived through the ears, including spoken sound, music, sound effects, or other noises.
- **Tactile**: Any output that can be perceived via the user’s sense of touch, including haptics and vibration.
- **Visual**: Anything coming into the user’s eyesight, primarily through screen-based displays, but may also include projectors, lights, physical object movement (e.g., a robot’s eyes blinking), or e-ink displays.
- **Other**: Although less common than the other three, there are other ways that computing devices can provide output including gustation (taste), olfaction (smell), thermoception (heat), nociception (pain), or equilibrioception (balance).

2.2.3 DOMAIN

This category refers to the focus area relevant to autism that the technology targets, such as helping with acquisition of certain skills or addressing certain challenges.

- **Academic Skills**: Includes applications that focus on skills traditionally taught in educational institutions, including math, science, letters, shapes, colors, etc. Language skills would be an academic skill, but because they are often a primary focus for other applications, we included them in their own category. With expanded attention to adolescents and adults, this category also includes a push towards postsecondary education. However, employment-related technologies, are left in the vocational skills section described below.

- **Behavior**: Includes applications that focus on promoting positive behaviors and reducing negative behaviors. This includes repetitive or circumscribed behaviors, interests, or play. May also include both high-level cognitive behaviors and low-level behaviors, such as manipulation of body or objects.

- **Cognition**: Includes applications that support improvement of cognitive functioning, including memory, attention, and information processing.
• **Language/Communication:** Includes applications or projects that focus on learning vocabulary, language acquisition skills, reading, spoken language for communicative purposes, semantics, syntax, morphology, or prosody.

• **Life/Vocational Skills:** Includes skills that allow autistic people autonomy while conducting daily tasks in home, work, or social environments. Includes skills such as clothing, toileting, meal times, time management, transportation, safety, scheduling, and workplace skills.

• **Play:** Includes applications that promote play to engage in learning and play-based activities. Can include both structured and unstructured play activities.

• **Responding/Motor:** Includes applications that focus on an individual's response to stimuli, as well as movement, including fine motor, gross motor, motor fluency, posture, and gestures.

• **Sensory/Physiological:** Includes applications that focus on an individual's sensory or physiological responding, such as perception, activation, recovery, or regulation.

• **Social/Emotional Skills:** Includes applications or projects that focus on emotion recognition, prosocial behaviors (e.g., turn-taking, sharing, etc.), nuances, and figures of speech. In some cases, this consideration includes non-autistic people adapting to and supporting autistic sociality.

### 2.2.4 GOAL

This category refers to the primary goal of the technology itself. Some technologies related to autism are intended to screen or diagnose, whereas others are intended for interventions.

• **Functional Assessment:** Includes applications or projects focused on the collection and review of data over time to assess an individual's learning, capability, or level of functioning. The data collected is intended for end users and/or people caring directly for individuals with autism.

• **Diagnosis/Screening:** Includes applications that assess the risk of an autism diagnosis in the general population, or that assist in helping make or understand the severity of an autism diagnosis.

• **Intervention/Education:** Includes applications that attempt to improve or produce a specific outcome in an individual with autism. May focus on teaching new skills, maintaining or practicing skills, or changing behaviors.
2. METHODS AND CLASSIFICATION SCHEME

• Scientific Assessment: Includes applications or projects that use technology in the collection and analysis of data by researchers to understand more about autism and its features or characteristics.

• Parent/Clinical Training: Includes applications that provide support for caregivers, educators, clinicians, and other professionals to further their own learning and education or improve skills.

2.2.5 TARGET END USER

This category focuses on the person or persons who actually interact with the technology itself and are considered the primary users. It does not include secondary stakeholders or those who may benefit from the technology but do not actually interact with or use it.

• Person with Autism: Includes autistic infants, youth, adolescents, and adults. Diagnosis can be anywhere on the autism spectrum or self-identification without a formal diagnosis.

• Family/Caregiver: Includes anyone who cares for or supports anyone with an autism diagnosis or who self-identifies as autistic. May include parents, siblings, other family, friends, volunteers, group home staff, etc.

• Peer: Can be an adult or child who is a peer to autistic people. Includes both neurotypical individuals as well as those with autism or any other disabilities or chronic conditions. Recognizing the potential overlap with the caregiver category, this group includes people who typically do not perform explicit caregiving activities, such as co-workers. However, of course, as is true for all people, our peers often provide care informally and on an ad hoc basis even when that is not how they primarily identify in their relationship.

• Professional: A paid professional who works with autistic people. May include medical professionals, doctors, occupational therapists, physical therapists, speech therapists, applied behavior therapists, or other allied health professionals. Also includes educators and community support providers, such as those who teach or are otherwise involved in the education of students with autism in schools (public or private), including teachers, administrators, school staff, etc. and those who support autistic people in overcoming barriers to postsecondary education and employment, such as job coaches or transition specialists.
• *Researcher:* Anyone intending to collect data or conduct studies about individuals with autism and publish something generalizable about obtained data.

### 2.2.6 SETTING

The care of individuals with autism takes place in a number of different settings. This category refers to the settings or locations in which the technology is intended for use.

• *Clinic:* A place of professional practice that is not intended for education, such as a doctor’s office, therapist’s office, or a specialty service provider.

• *Community/Workplace:* Technology is intended for use while the person is in public places like parks, stores, restaurants, etc. and/or places of employment.

• *Home:* An autistic individual’s personal and/or shared living space.

• *Research Lab:* Technology is intended for use in a research laboratory under careful observation or for controlled settings.

• *School:* A public or private place for educating individuals with autism. Includes both schools that specialize in autism education as well as general, inclusive classrooms. Could be at all levels from preschool through postsecondary education.

### 2.2.7 PUBLICATION VENUE

Technology for autism is inherently interdisciplinary, and these disciplines have large variations in expertise and research approaches. This category describes the field from which the research publication originated.


• *Computing:* Journals, conference publications, and other publication venues relating to the fields of computing, computer science, or human-computer interaction. Often included in the Association of Computing Machinery (ACM) or Institute of Electrical and Electronics Engineers (IEEE) digital libraries. This field traditionally publishes in}

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\(^4\) [http://www.itasd.org/](http://www.itasd.org/)

- **Education**: Journal articles or publications focusing on education or special education. Often included in the ERIC digital library. Examples: *American Journal on Intellectual and Developmental Disabilities*, *Mental Retardation*, and *Journal of Mental Health Research in Intellectual Disabilities*.

- **Medical**: Journal articles or publications from the medical field, including health informatics or general mental health. Often included in the PubMed digital library. Examples: *Journal of the American Medical Association* (JAMA), *Journal of the American Medical Informatics Association* (JAMIA and AMIA conference), and *Journal of Mental Health*.

- **Social/Behavioral Science**: Journals or publication venues from areas in psychology, human development, or sociology. Examples: *Journal of Consulting and Clinical Psychology*, *Child Development*, and *Behavior Research Methods*.

### 2.2.8 Empirical Support

Many technologies that have been designed related to autism are experimental and may not be scientifically proven yet. To help readers distinguish between these types of technologies, this category describes the type of study that has been completed with the technology in terms of its feasibility, usability, acceptability, efficacy, and effectiveness. We note that in the field of human–computer interaction, smaller N studies are common due to the cumbersome nature of doing rigorous evaluations of novel and often non-robust technology prototypes, and thus feasibility studies are more common. Meanwhile in transition specialties and special education, as well as increasingly in health sciences, “N of 1” studies are increasingly acceptable. In addition, we note that the three levels within this classification are fairly broad. Within a given category, there may be varying levels of quality in terms of study design, number of participants, and level of control.

- **Descriptive**: Study design seeks to observe natural behaviors without affecting them in any way. Common approaches include observational methods (e.g., ethnography), case study methods, and survey methods.
• **Correlational/Quasi-Experimental**: Study design involves comparing groups, without any random pre-selection processes, on the same variable(s) to assess group similarities/differences and/or determine the degree to which variables tend to co-occur or are related to each other. They are similar to experimental study designs but lack random assignment of study participants. Common approaches include nonequivalent groups design, regression-discontinuity design, retrospective designs, and prospective designs.

• **Experimental**: Study designs seek to determine whether a program or intervention had the intended causal effect on study participants. There are three key components of an experimental study design: (1) pre-post test design, (2) a treatment group and a control group, and (3) random assignment of study participants. Common approaches include randomized controlled trials, Solomon four-group design, within-subject design, repeated measures design, and counterbalanced measures design.

### 2.2.9 TECHNOLOGY MATURITY

This category describes the maturity of the technology used with individuals with autism and its readiness for use or distribution by the general public.

- **Design Concept/Prototype**: The technology is not yet functional. It may be an idea expressed as a sketch, storyboard, interface mockup, etc. May also include non-functional but interactive prototypes such as paper prototypes, Wizard-of-Oz prototypes, video prototypes, demos, etc.

- **Functional Prototype**: A functional prototype has been developed and interacted with the intended users for the target purposes. It has been built for use by the developers to answer specific questions, but may require assistance with setup, use, or maintenance.

- **Publicly Available**: The technology is mature enough that it can be used without assistance from the developers or research team. This might be a commercial product, software that is open source, or applications available for download on websites or on mobile marketplaces. At times, the product was commercially available at the time of review and is not any longer. Commercial enterprises fail. However, in this case, we still categorize the product as being commercially available, because it was so at the time of the original research.

### 2.2.10 INVOLVEMENT OF INDIVIDUALS WITH AUTISM

It is important to recognize that technology designs are more likely to be successful when the people for whom the technology is designed are included in the design process. To this end, we
wanted to recognize and establish the importance of including individuals with autism in the design of technology tools. Druin (2002) pioneered a framework for assessing how children can be involved in the design of technology, ranging from “as users” to “as design partners.” Although this framework was initially intended for inclusion of children in the design process, we believe this framework applies similarly to other marginalized and potentially vulnerable populations. For each of the dimensions, we describe whether and how the autistic individual’s inclusion was incorporated into the design of the tool.

- **As Users**: Individuals with autism are primarily using technology not designed with their involvement. They may have participated in studies where they are observed using the technology and the results of their use may be published, but the technology was not knowingly used to affect the design of the system.

- **As Testers**: Individuals with autism were involved as testers of the system, and the results of the testing of the system were used to modify and/or improve the system’s design. This could happen early in the process through using low-fidelity prototypes and/or later in the process with fully functional systems.

- **As Informants**: Autistic individuals were involved early in the design process and may have contributed some of the initial ideas through participatory design workshops where they help ideate or prototype new ideas.

- **As Design Partners**: Individuals with autism were involved through the entire process and were made to be as equal of partners as possible, with special consideration taken to build relationships between the individuals and the design team.

### 2.3 SUMMARY OF CLASSIFICATION SCHEME

As an example of how we applied the classification, Abaris (Kientz et al., 2005; Kientz et al., 2006), an application that uses digital pen and paper input, speech recognition, and video recording and playback for supporting therapists conducting discrete trial training therapy, would be categorized as:

- **Input Modality** of Audio and Physical
- **Output Modality** of Audio and Visual
- **Domains** of Academic Skills, Life/Vocational Skills, and Language/Communication Skills
- **Goals** of Functional Assessment and Intervention/Education
- **Target End Users** of Professionals
Figure 2.1 includes 26 papers on technologies reviewed for this book and their associated coding within the classification scheme as a demonstration of the coding scheme. We chose the 26 papers based on their diversity across specific areas within the classification as a way of defining, refining, and testing our scheme’s components. This list of papers was expanded and updated in the second revision of this book.

In the subsequent chapters, we use this scheme to describe the different types of interactive technologies. The chapters are organized based on groupings of technology platforms and specific differentiators that are most relevant to the systems, similar to what has been used by other systematic review articles (e.g., Grynszpan et al., 2013). The subsequent chapters include Personal Computers (Chapter 3), Mobile Technologies (Chapter 4), Shared Interactive Surfaces (Chapter 5), Virtual and Augmented Reality and Multi-Sensory Environments (Chapter 6), Sensor-Based and Wearable (Chapter 7), Natural User Interfaces (Chapter 8), and Robotics (Chapter 9). Some applications and technologies might fit into more than one of these categories (such as both mobile devices and a shared interactive surface). We discuss those as part of each chapter and co-reference where appropriate.

Within each chapter, we have included a section that discusses exemplary technology platforms from among the 26 papers used to develop the classification scheme. We describe how these technologies fit within the rest of the scheme beyond the technology platform and then provide a discussion of the overall trends we saw for the given platform. We also discuss opportunities for future work and identify areas that may be of interest to new researchers.

We note that this review provides a snapshot of the current landscape of interactive technologies for autism, and that technology is always evolving and changing, as is our knowledge about autism and cultural expectations about language, inclusion, and diversity. We expect that there will be many new technologies identified beyond those discussed in this review. To keep the community up to date, we have started a public, shared Mendeley.com group called “Interactive Technologies for Autism” that contains all of the references cited in both this book and the previous edition.5 We welcome the community to add additional references, comment on existing ones, and add tags to references to classify them in our scheme. We also believe the classification scheme may evolve as technologies evolve, and we welcome a discussion of this through the Mendeley group.

5 http://www.mendeley.com/groups/3745371/interactive-technologies-for-autism/
**Figure 2.1:** Coding of 26 papers used to define, refine, and test our classification scheme (continued on following page).
Figure 2.1: ...continued.
CHAPTER 3

Personal Computers and Multimedia

Use of technologies in support of autism began with the advent of the desktop computer in the late 1970s and early 1980s. The expansion of internet technologies in the last two decades has broadened this scope as well, but we here include those systems with a traditional “desktop” model to them even if people are now accessing them on a wide variety of internet-connected devices. The experience of using these applications usually requires an individual to sit at a screen and use a keyboard and/or mouse to interact with specially designed software in a primarily stationary and seated position. While many of the examples provided in this chapter include applications that have since transitioned to smaller and mobile platforms, we highlight here applications that were initially developed for the stationary platform. A prominent use of the “desktop” platform involves the use of multimedia (e.g., image, video, audio, and combinations thereof) to support teaching and assessment of autistic individuals. This use of video and holds a particularly prominent place in the space of technologies for autism. Although use of multimedia features in other technology reviews in other chapters of this review, in this chapter, we particularly focus on the capture, storage, and/or access of a combination of text, audio, still images, animation, video, or interactivity content forms. It also includes interactive videos, DVDs, or other multimedia, which had an explosion of interest in the late 1990s. We particularly highlight ways in which video is a mode for both collection and delivery of information. We note that due to the changing nature of technology, this chapter is more of a historical overview and less of a review of current trends, as very little recent research in this space has focused exclusively on the personal computer, the web, or multimedia as a platform.

3.1 OVERVIEW OF PERSONAL COMPUTERS, WEB, AND MULTIMEDIA

The first personal computers were made available to the general public in the late 1970s and early 1980s, with platforms such as the Apple II, TRS-80, and Commodore 64. The internet and the World Wide Web (or the Web) became popular a little over a decade later with the invention of the first web browser, Mozilla, in 1992 and the launch of Netscape in 1994. Coincidentally, the rising popularity of computers and the internet followed a similar timeline with that of the rise of awareness and diagnostic rates of autism. Thus, it is somehow fitting that computers have become so popular with individuals with autism, though we are certainly not suggesting this is causal.

For the purposes of this review, personal computers and the Web as a platform includes applications that use a traditional keyboard, mouse, and monitor, and internet-based applications