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HUMAN–ANIMAL INTERACTION AND THE DEVELOPMENT OF EXECUTIVE FUNCTIONS

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Children, indeed, people of all ages, are affected in many positive ways by interacting with pets and companion animals. Human–animal interaction (HAI) can be socially, emotionally, physically, and cognitively beneficial. Our particular speciality happens to be executive functions (EFs), those vitally important mental processes that form the basis for strategizing, paying attention, prioritizing competing tasks, maintaining self-control, and adjusting to ever-changing situations. In this chapter, we examine the potential effects of HAI on EFs, starting with a broad overview of what EFs are and factors that influence them. Although there is currently little, if any, research that specifically demonstrates the link between EFs and HAI, the potential benefits of HAI for EFs hold promise for enhancing EF functioning in both children and adults.

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EXECUTIVE FUNCTIONS

EFs are top-down processes we recruit when it would be insufficient, detrimental, or impossible to go on autopilot or rely on habitual or instinctive reactions. EFs are also sometimes referred to as *executive control* or *cognitive control* (Espy, 2004; E. K. Miller & Cohen, 2001). The three core EFs (Diamond, 2013; Miyake et al., 2000) are *inhibitory control* (including self-control and attentional control), *working memory* (WM), and *cognitive flexibility* (also known as *mental flexibility* or *set shifting*). From those core EFs, higher order EFs (e.g., planning, reasoning, problem solving) are built (e.g., Collins & Koechlin, 2012; Lunt et al., 2012). Because they make it possible for us to think before we act, resist temptations, stay focused, mentally play with ideas, reason, and quickly adapt to changed circumstances, EFs are predictive of achievement, health, wealth, and quality of life throughout life, often more so than IQ or socioeconomic status (Moffitt, 2012; Moffitt et al., 2011).

Inhibition

Inhibitory control (also called *inhibition*) involves resisting a strong inclination to do one thing and instead doing what is most appropriate or needed (Diamond, 2013). It includes the self-control to resist temptations and not act impulsively (e.g., thinking before you speak or act so you don't do something you'd regret or put your foot in your mouth; waiting before rushing to judgment). It also includes the discipline to stay on task and complete what you started, resisting the temptation to quit because you're frustrated, bored, or more fun things are calling, and continuing to work even though the reward may be a long time in coming. It also includes screening out distractions so that you are able to concentrate, pay attention, and stay focused. Self-regulation overlaps largely, though not completely, with inhibitory control (Diamond, 2013).

Working Memory

WM refers to our ability to actively hold information in mind and work with that information—for example, reordering a set of items you are holding in mind, updating information, or doing mental arithmetic. WM is crucial for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier and relating that to what is happening now (e.g., keeping track of a conversation, relating what you are reading now to what you read earlier, understanding the relation between a later effect and an earlier cause).

Cognitive Flexibility or Switching

Cognitive flexibility refers to the ability to look at the same thing in different ways, from different perspectives, to think outside the box. If your way of solving a problem is not working, cognitive flexibility can help you conceive of the problem in a different way or approach it from a different angle. Cognitive flexibility builds on the other two core EFs and comes in later in development (Davidson, Amso, Anderson, & Diamond, 2006; Garon, Bryson, & Smith, 2008). Successful and fluid switching requires activating a new mind-set (loading it into WM) and deactivating (or inhibiting) the old mind-set. It is in this sense that cognitive flexibility requires and builds on inhibitory control and WM. Cognitive flexibility is also critical for adapting to change. You may be called on to flexibly change your plans when the unexpected happens, whether it is an unanticipated problem or obstacle or an unexpected opportunity or offer. Although the evidence for switching difficulty is most robust in early childhood and old age, even young adults in their prime find switching to be a challenge (Diamond & Kirkham, 2005; Koch, Gade, Schuch, & Philipp, 2010).

Researchers have agreed that the three constructs—inhibition, WM, and cognitive flexibility—are interrelated and interdependent. An improvement in either WM or inhibition is likely to lead to improvements in all three.

EVIDENCE ON THE IMPORTANCE OF EFs FOR DIVERSE ASPECTS OF LIFE

Healthy EF development is one of the most critical developmental tasks. One of the first places that a young child is called on to exercise EFs is at school entry, when he or she is required to remember and follow instructions and inhibit the inclinations to not wait in line, take what he or she wants even if another child happens to have it at the moment, or speak whenever a thought pops into mind. EFs have been shown to be more important for school readiness than IQ or entry-level math or reading skills (e.g., Alloway et al., 2005; Blair, 2002).

EFs are important for success throughout the school years, from the earliest grades through university (often more so than IQ; Duckworth & Seligman, 2005; Gathercole, Pickering, Knight, & Stegmann, 2004; Nicholson, 2007). This is hardly surprising considering that skills valued in academic settings (e.g., discipline, conscientiousness, not always putting one's needs and desires ahead of everyone else's, following instructions, finishing assigned tasks) rely heavily on EFs (Diamond, 2014a).

The importance of strong EFs does not stop in childhood. There is abundant evidence that EFs are crucial for success later in life in the workplace (Bailey, 2007), marriage (Eakin et al., 2004), weight control (Crescioni et al., 2011), staying out of jail (Moffitt et al., 2011), and resisting substance abuse (H. V. Miller, Barnes, & Beaver, 2011). Adults with better EFs also report they are happier and have a better quality of life (Moffitt, 2012).

In a study of 1,000 children born in the same city and same year, those with worse inhibitory control (children who were less persistent, were more impulsive, and had poorer attention regulation) when they were young, as adolescents were more likely to smoke, have unplanned pregnancies and drop out of school; as adults 30 years later they were likely to earn less, have worse health (3 times more likely to be addicted to drugs), be a single parent (twice as likely), or commit a crime (4 times more likely) than those who had had better inhibitory control as children, controlling for IQ, gender, social class, home lives, and family circumstances growing up (Moffitt et al., 2011). That is consistent with other evidence that early EF gains can reduce the later incidence of school failure, substance abuse and addictions, aggression, crime, other antisocial or inappropriate behaviors, and early death (Nagin & Tremblay, 1999; Vitaro, Barker, Brendgen, & Tremblay, 2012).

INTERVENING TO IMPROVE EFs

Improving EFs early is important because early intervention is far more effective and far less costly than trying to correct problems once they have developed. Economists have estimated a 16% to 18% return on investment from such early intervention (Rolnick & Grunewalk, 2007; Sege, 2011). Being able to enhance EFs early in a child's life is critical because it affects the trajectory (the negative or positive feedback loop) on which a child gets launched. Improving EF skills early gets children started on a trajectory for success. Conversely, letting children's EFs remain poor gets them started on a negative trajectory that can be extremely difficult and expensive to reverse. Indeed, it is quite likely that "interventions that achieve even small improvements in [the inhibitory control] for individuals could shift the entire distribution of outcomes in a salutary direction and yield large improvements in health, wealth, and crime rate for a nation" (Moffitt et al., 2011, p. 2694).

Happily, it is absolutely clear that EFs can be improved, even in very young children (e.g., Blair & Raver, 2014; Diamond, Barnett, Thomas, & Munro, 2007; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012). A surprisingly diverse array of activities each have at least one research study published in a peer-reviewed journal showing that they improve EFs, such as computerized training, martial arts, aerobic activities, yoga, meditation, noncomputerized

games, and certain school curricula (for reviews, see Diamond & Lee, 2011; Diamond & Ling, in press). Regardless of the type of activity, all activities that improve EFs have certain things in common, discussed here briefly.

- *Transfer of EF training is narrow.* Although improvement of EFs transfers, the transfer is narrow (Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2013; Park, Gutchess, Meade, & Stine-Morrow, 2007). People improve on the skills they train on, and those improvements transfer to other contexts where those same skills are needed, but people only improve on what they practice; improvement does not transfer to other unpracticed skills. For example, training on WM improves WM but not self-control, creativity, or flexibility. Thus, to see widespread benefits, diverse EF skills should be trained and practiced; then narrow transfer of each results in widespread gains across those skills. Real-world activities such as martial arts (e.g., Lakes & Hoyt, 2004) and certain school curricula (e.g., Blair & Raver, 2014; Diamond et al., 2007; Raver et al., 2011; Riggs, Greenberg, Kusché, & Pentz, 2006) train diverse EF skills and have shown more widespread benefits than targeted computerized training.
- *A lot of practice is needed.* When studying what makes an expert across an array of fields, Ericsson, Nandagopal, and Roring (2009) found that regardless of the field, it takes many, many hours of practice (they said 10,000 hours) to become expert at something. There is no substitute for putting in lots of hours. The same holds true for EFs: For EFs to improve, a lot of practice is needed (e.g., Bergman Nutley et al., 2011; Davis et al., 2011).
- *Progressively greater challenges to EFs are needed.* EFs need to be continually challenged, not just used, for improvements to continue to be seen. Ericsson et al. (2009) found that to get really good at anything not only takes many hours of practice but also practice of a certain kind: always pushing yourself to go just past the limits of your comfort zone (practice within what Vygotsky [1978] called the "zone of proximal development"). When one group is randomly assigned to EF training with difficulty continuously and incrementally increasing and another group to EF training where difficulty does not increase, researchers always find that those progressively challenged show more EF improvement than those who keep training at the same level (e.g., Holmes, Gathercole, & Dunning, 2009; Klingberg et al., 2005).
- *Benefits disappear when practice stops.* Studies have demonstrated that EF benefits can last months or even years, but they almost always grow smaller as the time since training increases (Ball et al.,

2002; Rueda, Checa, & Combita, 2012). It would be unrealistic to expect benefits to continue indefinitely once practice stops. For example, with repeated practice you might work up to being able to do 80 sit-ups at a time, but if you stop practicing, a year from now it is unlikely that you could do 80 sit-ups all at once.

- *Those with the weakest EFs benefit most.* Children at risk start school with worse EFs than their more economically advantaged peers (Hackman & Farah, 2009; Sarsour et al., 2011) and fall progressively further behind each school year (O'Shaughnessy, Lane, Gresham, & Beebe-Frankenberger, 2003). Improving EFs early might nip that dynamic in the bud. In other words, early EF training is an excellent candidate for reducing inequality (because it should improve the EFs of the most needy children most), thus heading off gaps in achievement and health between more- and less-advantaged children.

BRAIN REGIONS THAT UNDERLIE EFs

EFs begin developing during the first year of life (Cuevas, Swingler, Bell, Marcovitch, & Calkins, 2012; Diamond, 1991) and continue developing for over 2 decades (Crone, Wendelken, Donohue, van Leijenhorst, & Bunge, 2006; Davidson et al., 2006; Luna, 2009). EFs depend on neural circuits that include prefrontal cortex as a prominent node. Prefrontal cortex undergoes maturational changes even during infancy (e.g., Bell & Wolfe, 2007; Koenderink & Uylings, 1995) but takes over 2 decades to fully mature (e.g., Gogtay et al., 2004; Tamnes et al., 2013).

Other brain regions that play prominent roles in EF neural networks are the anterior cingulate cortex (Barber, Ursu, Stenger, & Carter, 2001; Milham, Banich, Claus, & Cohen, 2003), the parietal cortex (Dodds, Morein-Zamir, & Robbins, 2011; Olesen, Westerberg, & Klingberg, 2004), and the striatum (Lewis, Dove, Robbins, Barker, & Owen, 2004; Robbins, 2007).

SENSITIVITY OF PREFRONTAL CORTEX AND EFs TO EMOTIONAL, SOCIAL, AND PHYSICAL ASPECTS OF LIFE

Prefrontal cortex is the newest and most vulnerable region of the brain. If you are sad or stressed, lonely or socially isolated, sleep deprived, or not physically fit, prefrontal cortex and EFs suffer first and most. Conversely, you show much better EFs when you feel emotionally and socially nourished and your body is healthy.

Stress and Its Effects on EFs

Our brains work better when we are not in a stressed emotional state, and that is particularly true for prefrontal cortex and EFs (Arnsten, Mazure, & Sinha, 2012). One reason stress impairs EFs first and most is that even mild stress markedly increases levels of the neurotransmitter, dopamine, in prefrontal cortex but not elsewhere in the brain (overwhelming prefrontal cortex with dopamine so that it cannot function properly; Vijayraghavan, Wang, Birnbaum, Williams, & Arnsten, 2007). Indeed, stress can make us look like we have an EF disorder, such as attention-deficit/hyperactivity disorder, when we do not. One month of stress in preparation for a major exam disrupts prefrontal cortex functioning connectivity and impairs EFs (Liston, McEwen, & Casey, 2009). You may have noticed that when you are stressed, you cannot think as clearly or exercise as good self-control.

Sadness and Its Effects on EFs

When we are sad, we have worse attentional control (Desseilles et al., 2009; von Hecker & Meiser, 2005); when we are happy, we have better attentional control (Gable & Harmon-Jones, 2008). We are more creative, more likely to think outside the box, when we are happier (Ashby, Isen, & Turken, 1999; Hirt, Devers, & McCrea, 2008; Isen, Daubman, & Nowicki, 1987). (It's not that happier people are more creative than sadder people, but that in general a given individual tends to be more creative when he or she is happier than when he or she is more miserable.)

Loneliness and Its Effects on EFs

When we are lonely, our EFs also suffer (e.g., Cacioppo & Patrick, 2008; Campbell et al., 2006). When we feel more socially supported and less isolated, we show better EFs (Cacioppo & Patrick, 2008; Tangney, Baumeister, & Boone, 2004). Social relationships nourish us in many ways and even affect gene expression (Szyf, McGowan, & Meaney, 2008) and the way our neural networks behave, grow, and adapt to change (Jablonka & Lamb, 2006). We are fundamentally social; children who are lonely or ostracized are usually less able to show the EFs of which they are capable.

Exercise and Its Effects on EFs

EFs tend to be poorer in sedentary individuals (Hillman, Erickson, & Kramer, 2008). Physical activity, especially if it requires the use of EFs (e.g., yoga, Manjunath & Telles, 2001; or taekwondo, Lakes & Hoyt, 2004) improves

EFs. Exercise also improves mood (Lane & Lovejoy, 2001; Williamson, Dewey, & Steinberg, 2001) and sleep (Foti, Eaton, Lowry, & McKnight-Ely, 2011; Loprinzi & Cardinal, 2011), which are two avenues by which it might improve EFs, in addition to when it directly taxes them.

THEORY PROPOSED BY DIAMOND

Diamond (2012, 2013, 2014b) proposed that the activities and programs that most successfully improve EFs are not only those that directly train and challenge EFs but also those that indirectly support EFs by helping to reduce things that disrupt them (e.g., stress) and/or by increasing things that aid EFs (e.g., social support; see Figure 3.1). What activities directly train and challenge EFs and indirectly support them by also addressing social, emotional, and physical needs? Some of the activities that do that best are the arts (e.g., music making, dance, theatre), physical activities (e.g., team sports, martial arts, youth circus), and caring for animals. All of these train and challenge multiple EFs; they also relieve stress and provide joy, companionship, and physical exercise. Therefore, we predict that they should be excellent

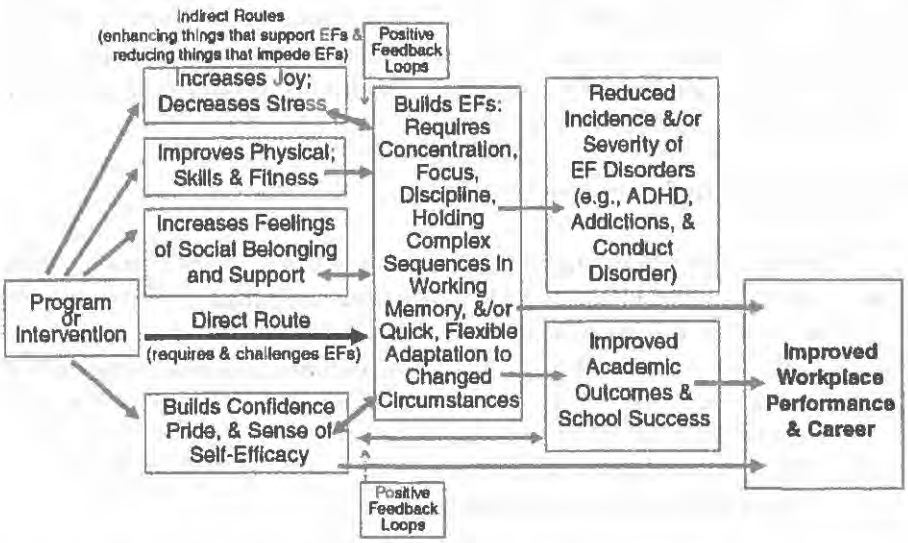

Figure 3.1. Illustration of a model put forward by Diamond (2012, 2013, 2014b) that postulates (a) that the activities that will most successfully improve EFs are those that require and directly challenge EFs but also indirectly support EFs by reducing things that impair them (e.g., stress) and enhancing things that support them (e.g., social belonging) and (b) that from that, better school and workplace performance and the reduced incidence and/or severity of EF disorders will follow.

candidates for improving EFs. Key is that an individual really enjoy the activity and really want to do it, so he or she will spend a lot of time at it, pushing himself or herself to improve. The best possible reason for anyone to want to keep at a difficult task is that he or she enjoys it.

CARING FOR AN ANIMAL REQUIRES EFs

Taking care of an animal provides many opportunities for the daily exercise of EFs. The responsibility of caring for a pet—remembering to walk, feed, groom, and keep the animal healthy—is an opportunity to exercise and train WM and inhibitory control. Continuous pet care over a long period (pets never grow up to be self-sufficient) taps inhibitory control and WM (focusing on a pet's needs even when you'd rather be doing something else or feel pressed for time, such as remembering when to give medications or to not place delicious human food too easily within reach of a pet, or forcing oneself to do things that are not so appealing, such as cleaning up poop). Training and taking care of an animal requires consistency.

Caring for an animal's needs provides opportunities for learning and exercising responsibility, even in very young children, and responsibilities can be incremented over time (gradually taxing EFs more and more). Young children can be taught, for example, to feed the family pet at specific times or to check that the pet has enough water. Children can also be involved in following the vet's instructions for giving medications and/or keeping the pet on a special diet. Repeatedly practicing responsible behaviors in caring for an animal can help make those behaviors more engrained and second nature. If you perceive yourself as a responsible pet owner, you might come to see yourself as a responsible person in general and act more responsibly in other realms. In short, within one's familiar home environment, caring for a pet can provide many occasions for EF skills to be exercised and nurtured.

HAI REDUCES STRESS

Many dog owners feel safer having a dog at home. There is evidence that in the face of anxiety-provoking stimuli, an animal's presence can help shift our attention from feeling helpless to feeling more hopeful and able to do something about the anxiety (Brickel, 1982; Shiloh, Sorek, & Terkel, 2003). The act of stroking an animal can relieve stress. Having companion animals present during anxiety-provoking procedures helps reduce children's distress (in pediatricians' offices, Hansen, Messinger, Baun, & Megel, 1999; Nagengast, Baun, Megel, & Leibowitz, 1997; during hospitalization, Tsai,

Friedmann, & Thomas, 2010; in their own homes/neighborhoods, Bryant, 1985; or general distress [e.g., bad day], McNicholas & Collis, 2001). Pets (especially dogs) also act to mediate stress levels in children with insecure attachment relationships (Beetz, Julius, Turner, & Kotrschal, 2012; Beetz et al., 2011). There are indications that just having an animal in the room reduces anxiety, allowing energy to be used more constructively for the tasks at hand. An increasing body of evidence shows that HAIs have a positive influence in the workplace. For example, dogs in the workplace have been found to reduce employee stress and increase team cooperation (Barker, Knisely, Barker, Cobb, & Schubert, 2012).

HAI IMPROVES MOOD AND GIVES JOY

Animals, especially dogs, express such exuberant joy on seeing their owner or someone familiar that it cannot help but make the recipient, and often observers, happy as well. Baby animals are so cute that they often bring smiles to our faces. To see the joy of animals when they are playing or outdoors running can also lift a person's spirits. An animal will sometimes explicitly try to lift someone's spirits by licking or nuzzling the person. HAI can help us see ourselves as better people ("If Boxer is so happy to see me, maybe I'm not so bad after all"), causing us to feel happier about ourselves. When we give an animal joy (e.g., by petting his coat, rubbing his belly, or giving him exercise), we get the great sense of pleasure that comes from making someone else happy, and it seems to take so little to cause an animal joy.

The presence of a dog in the classroom has been shown to help children exercise better EFs and perform better academically. That effect is credited to the dog reducing stress and improving the mood of the people in the classroom (teacher and students), allowing energy to be used more constructively for the tasks at hand. Preschoolers require fewer instructional prompts, are better able to keep their attention focused on their work, make fewer errors, and work more efficiently when there is a dog in the classroom (Gee, Church, & Altobelli, 2010; Gee, Crist, & Carr, 2010; Gee, Harris, & Johnson, 2007). The presence of an animal has also been shown to help children with cognitive impairments (Nathanson, 1989; Netting, Wilson, & New, 1987), pervasive developmental disorder (Martin & Farnum, 2002), and Down syndrome (Limond, Bradshaw, & Cormack, 1997) sustain focused attention longer.

Equine therapy (also known as hippotherapy) can provide children who have physical challenges (e.g., who cannot walk unaided or are normally confined to a wheelchair) with a sense of autonomy and accomplishment ("I can do this!") and provide them with a sense of pride as they sit tall, heads above those standing on the ground (All, Loving, & Crane, 1999; Granados & Agís, 2011).

HAI EASES LONELINESS AND PROVIDES COMPANIONSHIP

For centuries, animals have been welcomed into our homes in exchange for their love and companionship. Veevers (1985) suggested that a companion animal can substitute for, or complement, human interaction and can facilitate human interaction by acting as a bridge between people.

Pets help their human owners feel less lonely (Barker et al., 2012; Hunt, Hart, & Gomulkiewicz, 1992). This has been seen in people living alone (Zasloff & Kidd, 1994), children with disabilities (Mader, Hart, & Bergin, 1989) and without (Bryant, 1985; Covert, Whirren, Keith, & Nelson, 1985; Melson & Schwarz, 1994), rural youth (Black, 2012), and the elderly (Scheibeck, Pallauf, Stellwag, & Seeberger, 2011).

Dogs do not hold a grudge but give us unconditional positive regard; they love us no matter what. They also give us someone to love. They are always there for us. We can talk to them to hear ourselves think out loud, vent emotions, or try out different scenarios. If we want to go outside, they are always delighted to accompany us. Dogs do not require eye contact; those who find eye contact overwhelming or stressful often find interacting with dogs easier and more pleasant.

Having a pet can facilitate social interaction and act as a bridge to human interaction. It can be easier to start a conversation with "Oh, what a cute dog!" and someone too timid to speak directly to another person will often speak to the dog that person is walking. Walking one's dog also provides an opportunity to get out and meet others and socialize with one's neighbors (Friedmann & Thomas, 1985). It has consistently been found that companion animals help older individuals navigate the social circle, and that acts as a buffer for their psychological well-being (Hart, 2006; Raina, Waltner-Toews, Bonnett, Woodward, & Abernathy, 1999).

It is noteworthy that children are better able to empathize and appreciate individual differences when they are attached to a pet (e.g., Thompson & Gullone, 2003; Walsh, 2009). We are more likely to prefer spending time with people who show empathy and appreciate nuances in our communication or personal style. Children benefit from more than just "having a friend"; in their relationships with their pets, they can safely practice social skills that they can then transfer to human relationships.

HAI CAN IMPROVE PHYSICAL FITNESS

Individuals with companion animals report higher levels of physical activity and fitness than those without animal companions (Raina et al., 1999; Scheibeck et al., 2011; Serpell, 1991; Yabroff, Troiano, & Berrigan,

2008). Physical activity (at least walking one's dog) becomes part of one's daily routine as a dog owner. Even if you don't feel like it or the weather is rotten, your dog needs to go out. Pet owners are more likely to have consistent physical activity throughout the week. Thus, attending to the basic needs of their dogs seems to help owners lead healthier lifestyles. Similarly, if you own a horse, your horse needs regular exercise several times a week. From an EF lens, it appears that pets can help get their human owners up and exercising, and with repeated practice that routine can become second nature.

Riding a horse also has other benefits for the body. It can help improve head and trunk stability (Champagne & Dugas, 2010; Shurtleff, Standeven, & Engsberg, 2009), gait and balance (Kwon et al., 2011), gross motor function (reviewed in Snider, Korner-Bitensky, Kammann, Warner, & Saleh, 2007; Sterba, 2007), and muscle strength symmetry (Benda, McGibbon, & Grant, 2003).

CONCLUSION

It would appear that HAI can readily provide natural opportunities for training, using, and practicing EF skills, while reducing stress and providing joy, companionship and social connection, and opportunities for physical activity. Thus, we predict that it should be an excellent way to improve EFs. The multilayered positive aspects of HAI for practicing inhibition and stretching WM, stress reduction, social skills building, and physical fitness hold the potential to create an extremely effective intervention. Given how important EFs are for success in all of life's aspects, such interventions are well worth exploring. No study has yet looked at whether HAI, in fact, improves EFs. Research is needed that not only looks at whether this effect exists, but also that examines causal mechanisms. Humans and animals have led intimately intertwined lives for millennia. Given what we know about optimizing EFs, it makes sense that HAI provides a positive context for fostering the development of EF skills.

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The Social Neuroscience of Human–Animal Interaction

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