Epilogue
7.1 Introduction

Through theory and applications, this thesis has argued for developing an outlook on rehabilitation medicine that takes inspiration from an action-systems approach. Taking the use of serious gaming as a case in point, Chapter 2 started by showing that the current generation of serious games that aim to be useful in reality fail to do so. The chapter presents the first study that tested for transfer from a myogame to prosthesis use, and showed that achieving transfer between tasks, even if the game is successfully learned, is far from trivial. The chapter moreover highlights the task-specific nature of the skill learned when myogaming—an aspect easily missed if one does not adopt an activity-based approach.

Faced with the lack of transfer effects, Chapter 3 showed what it takes for transfer to occur within the context of using EMG to perform a goal-directed task. It showed that in the early formation of an action system both environmental and anatomical aspects, as well as the relation between the two equally contribute to the skill that is being learned. In particular, it showed that although an action system is a functional unit, at least in early learning, the function to which it pertains is also differentiated relative to the anatomical structure that enables goal attainment. That is, while it may be unsurprising to find transfer based on retaining the same goal across performances, this study showed that merely retaining the same musculature for exploration will also enable transfer. The chapter ended by outlining some of the theoretical and practical implications.

Capitalizing on these findings, in Chapter 4, the goal, musculature and settings of the myogame are chosen such that we could expect transfer to prosthesis use. Since there are nonetheless many factors that differ between a myogame and grasping with a prosthetic simulator in real time, it took implementing additional goal-relevant feedback to successfully set up an action system that incorporated a myoelectric interface in such a way that it could be adapted to a prosthesis task in daily life.

Exemplifying the theory of action systems further, Chapter 5 introduced its approach to learning through a study of tool making behavior. Chapter
5 showed how an action system for creating tools forms out of cycles of perceiving and acting. It emphasized the principle direction in which learning, as the formation of an action system, moves: it increases its units to larger temporal-spatial scales and comes to rely more and more on the particulars of the task it aims to perform. Learning, that is, is considered as a process of increasingly relying on task-specific aspects of the environment.

Following these empirical studies, the thesis explored how the action systems perspective differed in its background assumptions from the traditional approach adopted in rehabilitation medicine. It was argued that the traditional “reductive” methods and theories inherently displace “emergent” initiatives. Consequently, it was argued that when it comes to motor learning the emergent perspective that gave birth to the theory of action systems should be given autonomy if it is to inform rehabilitation theories. Chapter 6 ended by concretizing the issues in terms of transfer. While traditionally transfer is a mere consequence of a covert learning process with little theoretical relevance, it was claimed that in the action-oriented approach transfer gains significance. Transfer, that is the change in performance of a task following the performance of another task, is taken as an empirical measure of continuity across tasks, which can help to understand the limits and possibilities of an action system.

In the remainder of this epilogue some of the most important implications of the findings presented above will be taken up and related to rehabilitation practice. The focus will be on three issues. First, the notion of “transfer” will revisited. Second, the use and limits of serious gaming will be discussed as they were encountered in this thesis. Third and finally, the epilogue will point out the value and reality of practice.

7.2 Transfer: from assumed similarity to visible differences

This thesis started by pointing out that embracing novel technology led rehabilitation science to increasingly remote and artificial solutions to motor (re)learning problems. The recent adaptation of serious games
being a case in point. Learning to master such games, and moreover getting them to be relevant for the daily lives of patients, it was argued, is far from trivial (see Chapter 2, 4 and 6). This emerging technology inadvertently made a new case for the relevance of theories of learning within rehabilitation science, and hence, for a multitude of perspectives that may inspire them. The argument was that as engineering solutions increasingly change the tasks that patients need to perform in order to improve ADL, we need a perspective that gives us theories that point back to ADL. The action perspective does this by not assuming underlying (computational) similarity, but by primarily acknowledging the differences across task ecologies.

One of the most important empirical tools to do so is by measuring transfer. As we have seen in Chapter 6, from a reductive point of view, when learning a skill, an underlying faculty is developed inside the learner and this faculty is then supposed to be actuated across different situations. Finding transfer across tasks is then evidence for having retained this underlying faculty. Practically, this conceptual scheme leads scientists to favor laboratory tests that tap into the underlying faculty directly over doing “messy” testing of transfer to a prosthesis task, let alone to an ADL task—testing that is hard to standardize and control experimentally. This I believe is the reason why, before the publication of Chapters 2 and 5, myogaming research had never looked into transfer to prosthesis use.

Similarity across tasks, from an emergent point of view, is achieved as a continuous outcome of situated performances over time and not the internal source of such performances. The limited case of transfer, from this point of view, is simply repeating a task. As one learns, having performed a task once readies the learner to refine on the next task performance (i.e. it allows one to do it better the next time around): there is thus “transfer” in an arbitrary way from one performance to the next when learning a task. The very fact that a task has been performed before makes a (quantifiable) difference to subsequent performance. During learning, the functional fit between the organism and its environment becomes tighter (see Chapter 3 and 5).
However, in order to remain functionally adapted to an ever changing environment it has been stressed in this thesis that learning should be conceptualized as a process of “differentiation” (J. J. Gibson & E. J. Gibson, 1955). Through exploration, the system aims to notice differences, rather than similarity, across situations (see e.g. Chapter 3 and 5). Within a task, learning a skill thus cultivates a selective openness to new possibilities for action (H. L. Dreyfus & S. E. Dreyfus, 1987; Reed, 1996; Rietveld & Kiverstein, 2014). By remaining open to adapt to the environment, a continuity across performances emerges despite changes in the environment (in which case one is said to have a “skill”). It is this continuity in the dynamics of the organism–environment system that is quantified in different ways by measuring either learning or transfer effects.

From this point of view, finding transfer across tasks, as we did in Chapter 3 and 4, thus teaches us something about the continuity in or stability of the fit that the organism-environment system has established as a whole. With respect to the acting organism, it shows to what extent the organism had remained open enough to achieve continuity in its relation to the changing environment over time.¹

Notice that this way of thinking about transfer is a reversal of the traditional view. If similarity is an emerging outcome of a developing organism-environment system, rather than the source of an organism’s performance, then a transfer effect is an empirical measure that characterizes the functional limits of the developing organism–environment system—that is, it helps to determine what aspects of a task are functionally relevant to the system as it has developed so far. As shown in Chapter 3, testing for transfer is then the principle method at our disposal for quantifying the development and functional limits of an action system.

¹One theory that comes close to formalizing this idea is the theory of direct learning (Jacobs & Michaels, 2007). It differs from the view I am trying to get at here, in that this theory assumes yet another, even more abstract, underlying similarity (in information) to account for the continuity over time. In the foregoing discussion I have been trying to steer away from this assumption.
7.3 The limits and use of serious gaming

Serious gaming in rehabilitation is a technological answer to a motor learning problem. Of course, serious games can have aims other than motor learning even within the context of prosthesis use. The loss of a limb has psychological and social dimensions that might be targeted, and serious games could also turn out to be beneficial in for example reducing pain, improving a patient’s image of the body, or reducing muscular atrophy. These possible applications however are beyond the scope of this thesis. In this thesis I have focused on the aim of serious games to provide skills that are useful in reality (Bergeron, 2006; Graafland et al., 2012), the question whether they have actually done so however, at least within the field of myogaming, remains to be answered. Herein lies an important task for future research.

An important reason why getting myogaming skills to be useful in reality is far from trivial resides in the reductive assumptions on which the design of serious games is based. The thesis has taken up the issue of a reduction of activities to body-functions at length. However, there is a second type of reduction that was not discussed and that serious gaming engenders: the reduction of the activity of the learner to the movement of an avatar (end-effector) on the screen.

Considering the reduction of the activity to its end-effector has not been explored in this thesis, but it is potentially of great importance. Looking at the experiment presented in Chapter 3 most of the situation that enables the myogaming tasks to be performed remains constant over sessions and across tasks. From the interaction with the experimenters, to the chair and layout of the room as well as much of what happens on the screen, all persists as a background to both training and testing performance. Rather than focusing narrowly on the goal on the screen, we should take note of the background coordination of the actual participant in the particular (and social) behavioral setting with which he is learning to cope (see e.g. the classic work of Lee & Aronson, 1974, see also Schöner, 1991, to get an idea of the importance of such background coordination).
In other words, the goal of the participant was not just to achieve a high score on the game, it was also to cope with a largely unfamiliar experimental situation—for which the game was merely a means. If, as I have suggested, transfer is a function of the continuity of the organism-environment system, then maintaining such standardization might be doing more than to reduce unwanted “contextual interference.” Minimally, it is the way this setting is furnished that allows for the events on the screen to make a difference to its behavior (Danziger, 1997; Heft, 2007), but it might also be this background coordination that accounts for much of the transfer (i.e. achieved similarity) across otherwise widely differing tasks. A true ecological theory of learning within rehabilitation science will have to start dealing with this. Future research needs to focus on this—both in its theory and in experiments—as it may be an important aspect to understand when aiming to transferring skills from virtual reality to that of the rest of our ecological niche. Moreover, the same principle might apply when transferring skills from experimental and clinical settings to the daily life of a patient.

7.3.1 A new hope

All this being said, the emergent perspective and the theory of action systems in particular offer important ways in which virtual technologies (chiefly serious games, but also virtual and augmented reality) might benefit skill acquisition. In Chapter 6 it was argued that serious gaming tends to cut up skills along body-functional rather than along task-functional dimensions. That is, if learning a skill is learning to differentiate and find the distinctions in the environment that matter to goal attainment, one way in which virtual technologies might foster motor learning is by adapting the task to the performers’ level of skill and then capitalize on the differentiation process to get the performers to the task of daily life it ultimately aims for. This can be done first by remaining close to the task of ADL and then adding particular feedback that enables the calibration process to function across tasks and second by simplifying the ADL task so that the exploration of the task space can be guided until the proper system has been set up. Let us briefly look at both in turn.
In Chapter 4 it was shown that if we add feedback to a gaming task that emphasizes the relative opening (and the closing force) of the virtual hand in such a way that it mattered to goal attainment, participants attend to these aspects in the prosthetic simulator task as well. From an action system perspective, this can be understood as having developed an action system in the training task that can be re-assembled and calibrated to fit the testing task. Such an interpretation also fits the observation that the opening of the prosthesis grew better adapted during the posttest as a proper calibration was achieved (see Figure 4.10). By having a gaming task be similar to the testing task (or the task in ADL) with respect to the information used for calibration, the game might enable transfer across performances. The next generation of serious games might hopefully develop such a theory further and design games accordingly.

A different way to get the most out of virtual technologies might lie in simplifying the task that the developing action system needs to perform. This can be achieved by making it easier to obtain and maintain a proper relation to perceiving and acting and then slowly but surely increasing the difficulty until the task gets a sense of ecological validity. In this way, serious games or other virtual technologies might help guide the exploring and differentiating action system towards the best, i.e. most ADL relevant, fit with its environment. In Chapter 3 we find some evidence for this idea in the fact that in an undifferentiated system, even a task such as intercepting a ball can help the system to improve performance of a grasping task despite a lack of similarity in goals. A possible interpretation of this finding was that the way in which the musculature was starting to get used, differentiated the system in such a way that it enabled an ability to quickly explore the testing task along a relevant dimension.

In principle, simplifying the task can be done not only by simplifying the action necessary to perform it, but also by simplifying the perceptual effects used to guide this action. Experimental evidence for this phenomenon comes from Mechsner, Kerzel, Knoblich, & Prinz, 2001, who had subjects rotate two pegs with their arms at a relative phase of 4:3. Normally, such a pattern is almost impossible to perform. However, by
transforming the pattern so that the 4:3 movements were seen as “simple” in-phase (1:1) movements of the pegs, the 4:3 movement pattern could be performed successfully. Although transfer to more complex perceptual feedback needs to be determined (see but Kovacs, Buchanan, & Shea, 2010), it will be particularly interesting both practically and theoretically, to find out to what extent such processes can help in the development of an action system. Virtual environments offer the appropriate tools to do so. They might offer an important way to scaffold a task to an individual’s needs in such a way that it will transform a virtual gaming skill to an everyday activity in daily life. It will be very interesting to see how future research might make use of these findings.

7.4 The reality of practice

In this thesis, we have seen the many realities of practice. First, the importance of transfer of skill was given new theoretical significance. It allowed us to bring out the importance of differences across concrete performances rather than remain focused on abstract similarities. Second and related, the action system approach brought into view the fact that a “virtual” task is a concrete task like any other and one that often has more differences than similarities with the tasks they “simulate.” Virtual reality is thus still a practical reality as any other. Third, the continued and even increasing importance of patients practicing and getting skilled for assistive technology to become effective technology was reasserted. This suggests that our ability to adapt and become skillful should not be engineered away but should be embraced and made use of—and serious games, as was argued above, might actually offer a way of doing so. Fourth, in this final section, one last reality of practice will be drawn out.

This final dimension of practice aims to make clear that the methods and tools at the disposal of rehabilitation science, as well as large parts of human movement sciences, force us down a particular reductive direction of inquiry. In this reductive view we start to look for the source of action in their “underlying” movements (see also Chapter 6). As Reed reminded us however: movements need not be considered the
constituents of action but can be viewed as measurable consequences of action. That is, by tracing displacements over time, we can focus on persistent aspects of action. Or we can, for particular purposes, define action in terms of stability or flexibility of movement (Schöner, 1995). We can even define them in terms of their environmental relata or in fully relational terms (e.g. Chapter 2 and 5). The thing is however, that none of these operationalizations (although often useful in particular cases) gets to an essence of action. They are always quantifying an aspect of action—and hence entail a transformation of that phenomenon, enabled by much more actions then we can hope to explain.

This does not make actions less real—quite the contrary. But it does make them harder to reduce to quantity. As William James pointed out, the perspective that takes movements as the source of action can be viewed as “abandoning the empirical method of investigation” (James, 1890/1950, p. 224). That is, our methods and definitions should not start to live a life of their own and taken as the source rather than the consequence of action. The final dimension of our reality of practice is thus the reality of our own scientific practice. It urges us to stop taking our empirical method for granted and take the merits and its limitations of our own empirical devices much more seriously—this is the most important recommendation for future research this thesis offers.

It is in fact the main change in perspective that this thesis has aimed to bring about. The perspective inspires to see the possibilities and limitations of our own scientific gains (see Chapter 1 and 6). It begs us not to let either the engineering protocols or empirical methods dictate the reality we are after. If we can adopt such a way of looking at our scientific practices, then we might just be able to remain open enough to allow for fundamentally new ways of approaching problems to emerge—and we may learn to see the value in developing theories along paths less traveled.