Development of metacognitive skills in young adolescents : a bumpy ride to the high road

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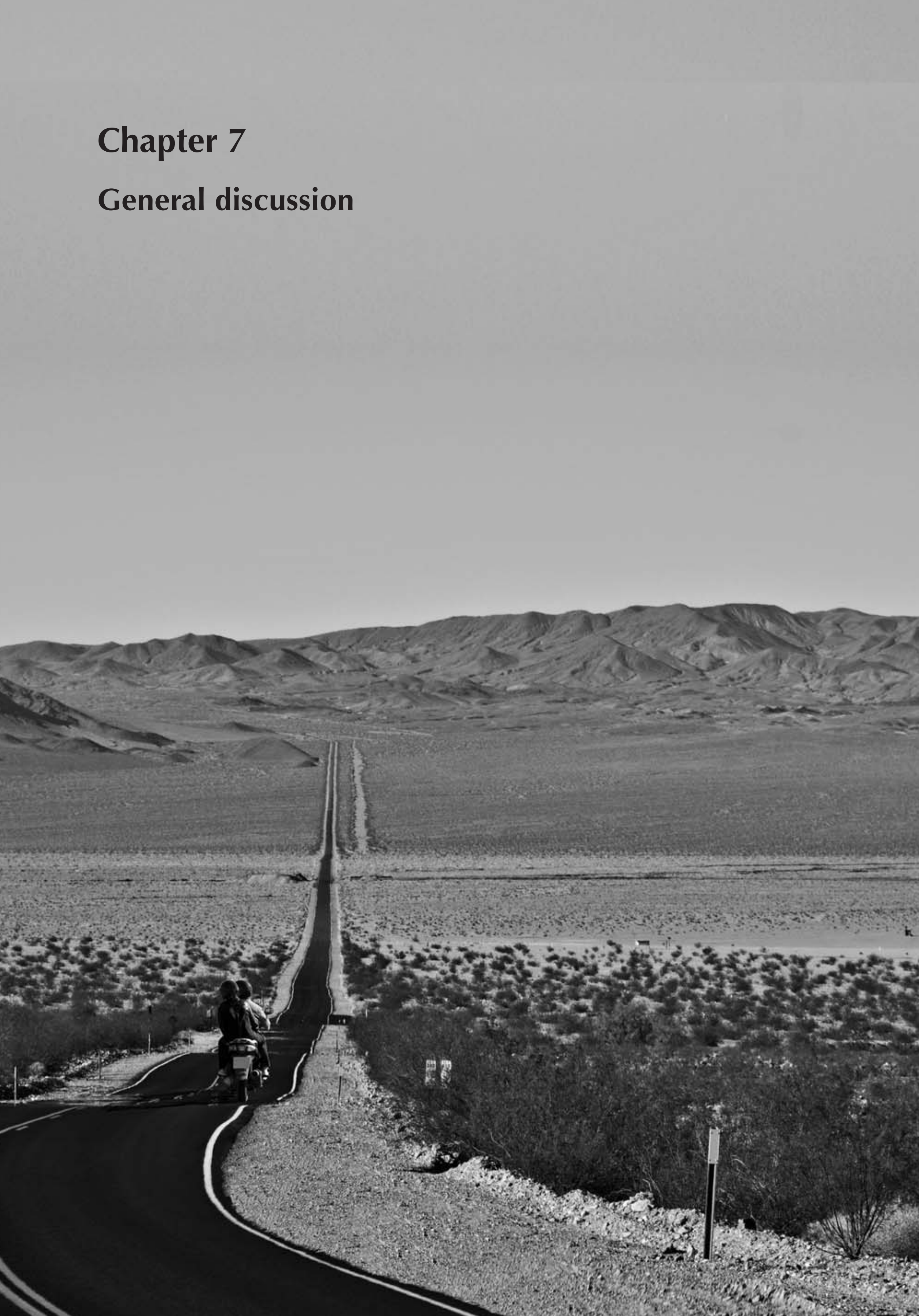
Chapter 7

General discussion



The studies in this thesis addressed developmental changes in metacognitive skillfulness in young adolescents aged 12 to 15 years. The research aimed to gain insight in (a) whether metacognitive skills grow in frequency and/or in quality during young adolescence; (b) how metacognitive skills relate to intellectual ability as predictors of learning performance during this period in life; (c) whether metacognitive skills are general or domain specific by nature in young adolescence. It was expected that metacognitve skills would show a continuous increase both in frequency and in quality (hypothesis 1). Furthermore, it was expected that metacognitve skills would have a unique contribution, on top of intellectual ability, to the prediction of learning performance. Moreover, it was expected that intellectual ability and metacognitive skills would develop in a monotonic way as predictors of learning performance (hypothesis 2). Finally, it was predicted that metacognitve skills would tend to generalize across development (hypothesis 3). In this final chapter, the findings of the longitudinal study (Chapters 2 – 4) and the cross-sectional study (Chapter 5) will be summarized and discussed.

7.1 Summary of the findings

7.1.1 Growth of metacognitive skills

Results from the longitudinal study concerning the growth of metacognitive skills were not quite as expected. Based on prior cross-sectional studies that investigated metacognitive skills from a developmental perspective (Veenman, Wilhelm, & Beishuizen, 2004; Veenman & Spaans, 2005), a continuous increase of metacognitive skills was expected. Between the first and the second year (13 to 14 yrs.) a substantial growth was found, indeed, in both frequency and quality of metacognitive skills. This growth, however, did not continue after the second year (between 14 and 15 yrs.). Only in one of the subscales, metacognition scores increased continuously over the three consecutive years, whereas most of the subscale scores leveled off or regressed in the third year. Results of the cross-sectional study in this thesis, on the other hand, did reveal a growth between 14 and 15 yrs. These contradictory results are rather remarkable, because the same math tasks were used for the same age groups in both the longitudinal study and the cross-sectional study. In conclusion, the findings in the longitudinal study do not allow for fully accepting the first hypothesis of this thesis.

On the level of subscales of metacognitive skills, two general developmental patterns were found: Growth between the first and the second year, followed either by stabilization or by regression. Only one subscale met the expectation of continuous growth over the three years. The quality of planning and evaluation activities in math increased between the first and the second year and then stabilized, whereas these activities increased in the cross-sectional study. The quality of elaboration activities in math was stable over the first two years and then regressed; in the cross-sectional study, no change occurred in elaboration activities. In history, the quality of orientation increased between the first and the second year and then stabilized. The quality of elaboration activities was stable over the years, while the quality of evaluation increased between the first and the second year and then regressed. For the quality of planning in history, it was the other way around. Quality of planning activities decreased between the first and the second year and then increased.

The frequency of metacognitive activities showed another pattern than the quality did. In math, the frequency of metacognitive skills increased in all subscales between the first and the second year in the longitudinal study. Between the second and the third year, however, frequency decreased, while there was an increase in frequency of metacognitive skills in the cross-sectional study (except for the number of orientation activities). In history, the frequency of orientation showed a continuous growth over the years. The number of planning activities increased between the first and the second year and then stabilized. Evaluation activities increased in frequency between the first and the second year and then regressed. For elaboration, it was the other way around; frequency of elaboration decreased between the first and the second year and then increased.

One salient conclusion can be drawn from the results of the longitudinal study: Metacognitive growth is not strictly continuous in young adolescents. In the current longitudinal study, most of the subscales of metacognition show discontinuity in growth between 14 and 15 years.

A relevant issue to discuss concerns the question why in the longitudinal study no continuous growth of metacognitive skills was found, whereas in prior cross-sectional studies (Veenman et al., 2004; Veenman & Spaans, 2005) linear growth was reported. Veenman et al. (2004) assessed metacognitive skills at the age of 9 yrs., 14 yrs., 17 yrs., and 22 yrs. They found a steep linear developmental growth over these four points in time. Veenman and Spaans (2005) found a strong growth in metacognitive skills between 13 and 15 years (first and third year in secondary education). It has to be noticed, however, that the interval between assessments was two years or more. If intervals of assessments are rather extended, growth mistakenly may be characterized as continuous, that is, uninterrupted, whereas growth may in fact not be continuous. In that case, results of the present longitudinal study would not contradict results of prior studies: Metacognitive skills show an overall increase between 13 and 15 years. So, it can be argued that over a more extended time span metacognitive skills will grow continuously, albeit with one or more period(s) of discontinuity within that time span.

A related issue concerns the fact that patterns of growth between 14 and 15 years in the present cross-sectional study (Chapter 5) only partly correspond with the longitudinal study of this thesis. Differences in interpretation of findings between the present longitudinal study on the one hand, and the studies of Veenman and colleagues, and the present cross-sectional study on the other hand, might be due to differences in design. Longitudinal studies might be more sensitive than cross-sectional studies to detect changes, for example discontinuity, in development. Any differences between groups are excluded by a longitudinal design with the same participants, thereby reducing the error of variance.

Methodological issues, like selective loss of participants or lack of consistency in rating throughout the consecutive years that can occur in longitudinal designs, could be responsible for the difference in results as well. Therefore, several checks were performed in order to ensure that methodological issues did not account for the difference in results (see Chapter 6). Despite methodological risks that are inherent to longitudinal designs, in the last decade several researchers in the field of cognitive and neurocognitive developmental studies advocated a more frequent use of longitudinal designs (Bullock & Schneider, 2009; Casey, Tottenham, Liston, & Durston, 2005; Crone et al., 2006). In their opinion, longitudinal designs would be more sensitive to detect and follow changes during development, relative to cross-sectional designs. In general, it does not become clear from cross-sectional studies whether results on developmental trends based on group means are also valid on the individual level. Improvements on the group mean level could be due to some children making enormous progress, whereas others remain stable or even decline. In a 10-year longitudinal study on verbal-memory development (Schneider, Knopf, & Sodian, 2009), it was found that individual children changed their relative position in the sample between two measurements. Therefore, the model that fits the group data does not always adequately describe intra-individual changes. Children showed leaps ("jumpers") and U-shaped curves in memory-strategy development. Thus, the pattern of linear growth indicated by the group mean development obtained from cross-sectional studies sometimes can be misleading.

Looking closer into the data of the present longitudinal study, some intra-individual changes are found too. Between the first and the second year almost half of the participants showed a 'leap'[9] (in problem solving the leap was predominantly forward; in text studying some leaped forwardly, others backwardly) in the use of metacognitive skills. Between the second and the third year about one third of the participants 'leaped', either forwards or backwards for both tasks. These intra-individual changes would have not been revealed in a cross-sectional study. They do not become clear either from group mean data in a longitudinal design that wash out individual differences. For example, it seemed that for some participants not much was happening regarding changes in applying metacognitive skills in text studying, whereas others showed rather big 'leaps'. From (neuro)cognitive developmental studies it is known that there is a large individual variability in brain structure among individuals, especially during development (Casey et al., 2005). Furthermore, in dynamic-systems theories (Siegler, DeLoache, & Eisenberg, 2010), a class of theories that focus on how change occurs over time in complex systems, it is stated that individual children acquire skills at different ages and in different ways, and that their development entails regressions as well as progress. Results of the longitudinal study are in line with this notion of individual variability. Young adolescents not only differ substantially from each other in their use of metacognitive skills, they also differ within themselves from moment to

9 Leap means a change of 50% or more

moment, or from task to task. During development, both progress and regression occur, and not all components of metacognitive skillfulness develop at the same pace. It seems that metacognitive skills are still in an unsettled developmental phase during young adolescence.

7.1.2 Metacognitive skills in relation to intellectual ability

As far as known, in this thesis the mixed model was tested for the first time in a longitudinal design, including both text-studying and problem-solving tasks. Previous studies that found evidence for the mixed model across age groups were studies with a cross-sectional design without text studying (Veenman et al., 2004; Veenman & Spaans, 2005). Further evidence for the mixed model was found in a number of non-developmental studies, including problem-solving or text-studying tasks (Elshout & Veenman, 1992; Veenman & Beishuizen, 2004; Veenman & Elshout, 1991, 1995, 1999; Veenman, Elshout, & Busato, 1994; Veenman, Elshout, & Meijer, 1997; Veenman, Kok, & Blöte, 2005; Veenman & Verheij, 2003).

Results of the present longitudinal study show that metacognitive skills had their own unique contribution, on top of intellectual ability, to the prediction of learning performance in line with the mixed model. In the three consecutive years, metacognitive skills had a unique contribution to the prediction of learning performance, regardless of tasks and domains. These findings are in line with results of the afore-cited studies that investigated the relation between intellectual ability and metacognitive skills as predictors of learning performance.

In the cross-sectional study of this thesis results corroborated the mixed model as well, with the exception of the frequency of metacognitive skills in 14-year-olds. The latter had no contribution to the learning performance at all. Both in the longitudinal and the cross-sectional studies of this thesis, the contributions of intellectual and metacognitive skills vary. Sometimes the contribution of intellectual ability outweighs the contribution of metacognitive skills; sometimes it is the other way around. Fluctuations in unique contributions over the years, however, were not significantly different (see Chapter 6). Therefore, results of this thesis allow for the conclusion that the mixed model is considered to be stable throughout the period of young adolescence.

Another important issue, addressed in the second research question, was to investigate whether the development of metacognitive skills is intelligence-related or relatively intelligence-independent. Alexander, Carr, and Schwanenflugel (1995) compared the metacognition of gifted vs. non-gifted children. They found support for a monotonic growth of metacognitive knowledge and intelligence. However, their results were inconclusive regarding metacognitive skills. In this thesis, the relation between intellectual ability, metacognitive skills, and learning performance was investigated from a developmental perspective. The monotonic development hypothesis is based on two presuppositions: A development of metacognition parallel to intellectual development, and the appropriateness of the mixed model for describing the relation between metacognition and intellectual ability as predictors of learning performance.

Two other developmental hypotheses, the acceleration hypothesis and the ceiling hypothesis (Alexander et al., 1995), do not relate to the mixed model. Instead, these models can be related to the intelligence model (Veenman, 1993) as the influence of intellectual ability on metacognition either increases or diminishes with age. Finally, the independency model (Veenman, 1993) fits none of Alexander's hypotheses, since it predicts that there is no relation between intelligence and metacognition at all. In the first and the second year of the longitudinal study, support was found for a parallel development of intellectual ability and metacognitive skills as predictors of learning performance. In this period, intellectual ability and most of the metacognition subscales increased significantly. After the second year, metacognitive growth was hardly found, apart from a few subscales of metacognition. In the cross-sectional study, however, significant growth between 14 and 15 years occurred in both intellectual ability and metacognitive skills. Apparently, the relation between metacognition and intellectual ability does not develop strictly according to the acceleration hypothesis, nor according to the ceiling hypothesis. Moreover, the relation between metacognition and intellectual ability does not fit better or worse with the intelligence model over age. Therefore, both the acceleration and the ceiling hypothesis can be rejected as a model for describing the relation between metacognition and intellectual ability during development. In the previous paragraph the discontinuity in metacognitive growth was discussed. If development of metacognitive skills is not strictly continuous, it cannot be strictly monotonic either. The monotonic development hypothesis (Alexander et al., 1995), however, is based on two presuppositions. The first one, that is, a development of metacognition parallel to intellectual development, was not found systematically over the years. The second one, that is, the appropriateness of the mixed model for describing the relation between metacognition and intellectual ability, was found systematically. Metacognitive skills keep on having their unique contribution to learning performance on top of intellectual ability, thus supporting the mixed model (Veenman, 1993). Although the various components of intellectual ability (numerical and verbal reasoning, visual-spatial ability, and memory), and metacognitive skills (orientation, planning, evaluation, and elaboration) did not develop all at the same pace, the overall relation between intellectual ability and metacognitive skills as predictors of learning performance was not affected. As stated above, the mixed model can be considered as stable in young adolescence. This means that the present findings corroborate the first part of the second hypothesis. In conclusion, results do not corroborate the second part: Metacognive skills did not always develop parallel to intellectual ability. Although the second hypothesis cannot be fully accepted, it was demonstrated that metacognitve development is not directed by intellectual development. The '*autonomous* development hypothesis' might be a more appropriate name for describing the relation between metacognitive and intellectual development, because metacognitive skills follow their own developmental trajectory in an autonomous way.

7.1.3 Generality vs. domain specificity of metacognitive skills

Results of the first two years of the longitudinal study showed that 13- and 14-year-olds resorted mainly to general metacognitive skills, but also to domain-specific metacognitive skills to a lesser extent. Metacognitive skills of 15-year-olds, on the other hand, appeared to be fully general. Relative to prior studies (Prins, 2002; Schraw et al., 1995; Veenman & Spaans, 2005; Veenman et al., 1997, 2004; Veenman & Verheij, 2003), the opportunity for finding domain specific and general components of metacognitive skillfulness was enhanced in this thesis by maximizing the difference between both tasks and domains at the same time. Problem solving in the domain of math was contrasted with text studying in the domain of history. Moreover, a broad range of metacognitive skills was assessed from thinking-aloud protocols in a longitudinal design, with measurement intervals of one year. By doing so, the conditions for detecting transitions in the domain specificity or generality of metacognitive skills over age were optimized.

Results of prior studies concerning the issue of metacognitive skills being general or domain specific were contradictory (Glaser, Schauble, Raghavan, & Zeitz, 1992; Kelemen, Frost, & Weaver, 2000; Schraw et al., 1995; Veenman & Beishuizen, 2004; Veenman, Elshout, & Meijer, 1997; Veenman & Spaans, 2005; Veenman & Verheij, 2003; Veenman et al., 2004). One of the reasons for contradictory results is dissimilarity between the studies (see Chapter 1, section 1.3). The study that is most comparable to the present study is the study by Veenman and Spaans (2005). In both studies 13- and 15-year-olds had to solve math word problems. In both studies it was concluded that between the age of 13 and 15 years a generalization of metacognitive skills took place, resulting in metacognitive skills being general for 15-year-olds. In Veenman and Spaans, however, metacognitive skills of 13-year-olds appeared to be predominantly domain specific. Apart from drawing a similar conclusion for the 15-year-olds, there were rather important dissimilarities between the two studies. First, tasks and domains differed to a lesser extent. In Veenman and Spaans participants had to perform an inductive learning task in the domain of biology and to solve math word problems. In the present study math word problems were contrasted with text studying in history. Secondly, the number of participants per age group was smaller in Veenman and Spaans (two age groups of 16 participants vs. *N*=25 in the present study). Furthermore, different methods for assessing metacognitive skills were used. Veenman and Spaans used systematic observation (math tasks) and log-file analysis (inductive-learning tasks). Because not all subscales of metacognitive skills could be assessed with log-file measures, log-file scores were validated by the analysis of a limited number of thinking-aloud protocols. Finally, another dissimilarity concerned the method of statistical analysis for investigating the generality vs. domain specificity of metacognitive skills: A correlational analysis (Veenman & Spaans) vs. a principal component analysis in the present study. So, Veenman and Spaans, and the current study show some crucial methodological differences that might explain the difference in findings concerning the 13-year-olds.

Schraw et al. (1995) suggested a compromise between domain-specific and domain-general hypotheses. They argued that domain-general monitoring skills emerge late in development and that they are preceded by modularized monitoring skills. In the same vein, Veenman and Spaans (2005) assumed that metacognitive skills initially develop on separate islands of tasks and domains and that beyond the age of 12 yrs. these metacognitive skills become increasingly general. Present results support the assumption that metacognitive skills tend to generalize across development, even if differences in tasks and domains were to be maximized. The generalization process, however, was less gradual than expected. Already in the first two years, the general component was much stronger than the domain-specific component and there was hardly any difference between the PCA solutions of the first two years. In the third year, however, the domain-specific component diminished rather abruptly. Therefore, it could be argued that prior to a final generalization, metacognitive skills are predominantly general, complemented with domain-specific skills. In conclusion, based on the present results the third hypothesis can be accepted. A future longitudinal study starting in primary school would more fully test the hypothesis that metacognitive skills start to develop on entirely separate islands and then tend to generalize with increasing age.

7.2 Conclusions

Reflecting on the results of the longitudinal study of this thesis, the overall conclusion is that between the age of 12 and 15 years growth in frequency and quality of metacognitive skills was not continuous. Various components (orientation, planning, evaluation, and elaboration) of metacognitive skillfulness developed in a non-synchronous way, that is, not at the same pace. Several scenarios were found in the development of these components: No growth at all; growth between the first two years followed by stabilization; growth in the first two years followed by regression. While between the age of 14 and 15 years further growth was found in a limited number of components of metacognition, another interesting change in metacognitive skillfulness occurred at the same time: Metacognitive skills of 15-year-olds no longer appeared to be partly domain specific, but became fully general.

From the cross-sectional study of Veenman et al. (2004), it became clear that metacognitive skills continue to develop till at least the age of 22 years. Therefore, it can be argued that in the long term metacognitive skills will continue to develop till late adolescence, but the developmental trajectory will probably know some temporary holds and leaps in growth. During these delays growth might give room to other developmental changes. In this case, growth could have made room for the transition of metacognitive skills from general and partly domain specific in the period between 12 to 14 years to fully general at the age of 15 years. This transition can be considered as a qualitative change that does not come without any effort of the learner. Therefore, this change may not go hand in hand with a further increase in frequency or quality of metacognitive skills, resulting in an intermittent growth at the age of 15 years. Maybe due to cognitive overload, growth and transition cannot develop at the same time, but occur alternately. Metacognitive skills are considered as procedural knowledge (see Chapter 1, section 1.1), that is, a production system of condition-action rules acquired in specific domains for specific tasks (Anderson, 1996; Veenman, 2011; Winne, 2010). The condition part of production rules triggers certain activities (actions) of the learner. When the reach or scope of these condition parts extends, production rules merge and can be applied more generally, initiating the transfer of production rules to other tasks and other domains. The intermittent growth of metacognitive skills could mean a temporary hold on the action part of production rules. They do not expand for a while as alternative actions parts of former individual production rules have to be tuned to the new, generalized conditions. This generalization process of conditions could be considered as a qualitative change for which the growth of action parts temporarily has to give way. Once students are capable of transferring metacognitive skills that were acquired in one context to another, different context, they will continue to increase the frequency and quality of their metacognitive activity.

Salomon and Perkins (1989) distinguished low-road from high-road transfer. Low-road transfer involves spontaneous, automatic transfer of highly practiced skills, with little need for reflective thinking. High-road transfer, on the other hand, involves the explicit conscious formulation of abstractions in one situation that allows for making a connection to another situation. In the same vein, Adams (1989) distinguished direct transfer from mediated transfer. The former involves a direct mapping from one problem-solving situation to another on the basis of superficial similarities between two problem situations, whereas the latter may transcend superficial differences between problem situations. In mediated transfer, students are capable of applying principles and procedures that have been abstracted from previous training problems to new situations. According to Salomon and Perkins (1989), low-road transfer comes as a result of extended practice in behaviors or cognitions. In contrast, high-road transfer results from mindful, controlled processes that decontextualize the elements that are to be transferred. It should be noted that Salomon and Perkins explicitly stated that metacognitive guidance appear to play a major role in high-road transfer. It can be argued that students could not apply high-road transfer -a conscious and metacognitively guided process-, and at the same time enhance the frequency and quality of their metacognitive skills. This could also explain the stabilization in growth at the time metacognitive skills tend to fully generalize. Future research must prove whether this explanation for intermittent growth is sustainable.

In summary, this thesis has shown that (1) Metacognitive skills do increase spontaneously in frequency and quality during young adolescence, albeit not continuously. The various subscales of metacognitive skillfulness do not develop at the same pace; (2) Metacognitive skills have their own contribution to the prediction of learning performance, on top of intellectual ability. The relation between intellectual ability and metacognitive skills as predictors of learning performance is not affected by development between 12 and 15 yrs.; (3) Around the age of 15 yrs. metacognitive skills become fully general.

7.3 Educational implications

In this section educational implications of two of the conclusions of this thesis are discussed. First, results obtained in this thesis show that metacognitive skills grow between the age of 12 to 15 years. It should be noticed, however, that this growth is not continuous, and that there are substantial differences in individual growth on the overall level, as well as on the various subscales of metacognitive skillfulness. Although spontaneous growth in metacognitive skills takes place, that is, growth without interventions that explicitly aim at training metacognitive skills, the developmental trajectory of metacognitive skills is a lengthy and 'bumpy' trajectory with alternating periods of progress, stabilization, and regression. Pressley (1986, p. 154): "Developing good strategy use is a formidable educational challenge, one that probably requires many years. Considered in this light, it is not surprising that few and small general effects follow from classroom interventions that span a semester…" A firmly-rooted use of metacognitive skills will neither develop totally spontaneously, nor can it be attained by short-term interventions. At the same time, however, in modern (secondary) education a lot is demanded from students in terms of taking responsibility for their own learning process by regulating, controlling, and reflecting (on) it. In other words, students need well developed metacognitive skills in order to be successful in secondary education. In many studies it was found that metacognitive skills in both problem solving and math (Cardelle-Elawar, 1995; Chinnappan & Lawson, 1996; Kramarski & Mevarech, 2003; Masui & De Corte, 1999; Veenman et al., 1994; Veenman et al., 2005) as well as in reading and text studying (Boulware-Gooden, Carreker, Thornhill, & Joshi, 2007; Houtveen & Van de Grift, 2007; Pressley & Gaskins, 2006; Souvignier & Mokhlesgerami, 2006) can be trained successfully. The interventions in the afore-cited studies were performed in widely varying age groups, school levels, and levels of intellectual ability. So, educators could foster the development of metacognitive skills by teaching them explicitly. There are three conditions for training programs of metacognitive skillfulness formulated in the literature (Veenman et al., 2006). In order to be successful, (1) training must be offered over an extended period of time, (2) students have to be convinced of the usefulness of trained skills (informed training), and (3) the skills to be acquired have to be trained in the context of a domain. Based on results of the current study, a fourth condition could be added, that is, metacognitive-skill components should be trained for which the time is right in terms of the developmental trajectory. The training of certain skills should be attuned to the spontaneous development of the same skills. For example, if young students of a particular age hardly reflect spontaneously, then, probably training reflection as metacognitive activity will not be very effective at that time. If, on the other hand, spontaneous reflection starts to develop, training will be more effective. Not only teachers, but also authors of methods for teaching should consider which component(s) of metacognitive skills has to be offered when. For example, in recent methods for teaching text comprehension in primary school much more attention is paid to metacognitive skills relative to older methods. Some of the recent methods are so-called concentric methods. In these methods, in every grade the same metacognitive skills are trained, albeit at different levels. It might be more effective to make a selection of skills, resulting in metacognitive-skill training that is more attuned to the developmental trajectory of that particular skill. For example, evaluation activities in history increased between 13 and 14 years. This could be an appropriate moment to foster this development as a teacher. By doing so and by stressing the importance of this particular skill in a critical period, the regression that followed the increase might be prevented.

Secondly, results in this thesis not only show a spontaneous growth in metacognitive skills, at least between 13 and 14 yrs., but also a spontaneous transformation of metacognitive skills to fully general skills. Nickerson, Perkins, and Smith (1985) noted that one especially prominent point in the teaching of metacognition is its relationship to transfer. According to them, there is the possibility of treating transfer itself as a metacognitive skill and attempting to train it directly. By doing so, generalization and transfer are no longer considered as "hoped-for-by-products" (p. 301) of teaching. Instead, students have to be made aware of the importance of transfer by giving them explicit instructions with respect to how to attain transfer. Brown (1978) argued that, as part of the training procedure, students should be informed that the skill they are acquiring can be useful in a variety of contexts. Next, they should be challenged in learning to recognize those situations for which a particular skill is appropriate. In other words, transfer itself should be taught as a metacognitive skill. So, educators are challenged not only to implement metacognitive-skill training within the scope of their own field, but also to generalize this instruction, to teach expectations for transfer, and to expect transfer beyond the boundaries of their field. Teachers of different disciplines should do so concurrently, while referring to one another during their classes (Veenman et al., 2004). Such coordinated teaching requires commitment of both the individual teachers and the school organization (Pressley & Gaskins, 2006).

Despite the proven usefulness of teaching and training metacognitive skills, teachers seem to have problems incorporating such training in their daily practice. Knowledge about the concept of metacognition often is lacking. In many cases metacognition is regarded as equivalent for 'learning to learn' or 'independent learning', without knowing how metacognitive-skill training should be implemented (Veenman, Kok, & Kuilenburg, 2001).

Waeytens, Lens, and Vandenberghe (2002) interviewed 53 secondary-school teachers about their subjective interpretations and the way they implement 'learning to learn'. The majority of teachers has a narrow sense of 'learning to learn'. In the opinion of these teachers, 'learning to learn' is limited to giving tips and general advice, mostly to younger and less able students.

Zohar (1999) found that teachers' intuitive (i.e., pre-instructional) knowledge of how to teach metacognitive skills is unsatisfactory for the purpose of teaching higher-order thinking in science classrooms. Moreover, most teachers are inclined to think that the teaching of strategy use and higher-order thinking skills is predominantly suited for students with high IQs (Zohar, Vaaknin, & Degani, 2001). Dignath and Büttner (2008) performed a meta-analysis on self-regulated learning interventions that were integrated in normal teaching contexts in primary and secondary schools. It was inferred from this meta-analysis that training programs performed by researchers (researcher-directed interventions) had better results than training programs performed by teachers (teacher-directed interventions), which may be the consequence of inadequate or insufficient teacher training. In order to take up their role as promoter of metacognitive skills in students, teachers should be thoroughly educated in the teaching and training of those skills.

7.4 Limitations and directions for further research

Due to the method chosen for assessing metacognitive skills (analyzing thinking-aloud protocols), it was not possible within the frame of this thesis to follow a large number of participants for more than three consecutive years. As a result, some limitations should be considered. One of the limitations is the rather small number of participants. Due to the labor intensiveness of analyzing thinking-aloud protocols of individual student sessions, it was not feasible to work with a larger sample. Another limitation is the fact that all participants came from the same school. Both limitations could have affected the generalizability of the results. Furthermore, the period of data collection, three consecutive years, was rather short relative to the entire period of adolescence. The period between 12 and 15 years offers an interesting, though limited window on adolescence. Finally, the current study relied on one particular on-line method for assessing metacognitive skills, that is, the analysis of thinking-aloud protocols. Thinking-aloud protocols depend on verbalization of executed skills with the risk of missing out highly automated skills that are not verbalized. Perhaps, thinking-aloud measures did not capture all metacognitive activities.

Knowing that brain maturation goes on till the early twenties at least, it would be very interesting to follow students for an extended period of time across development. A longitudinal design, starting in primary school (around the age of 8 years) and ending in late adolescence (around the age of 25 years), should be considered for future research. A more realistic, that is, pragmatic alternative might be an overlapping roof-tile construction of cross-sectional and longitudinal research combined in one study. In such a design, one group of participants will be followed for a number of consecutive years (e.g., at the age of 8, 9, and 10 yrs.), and another group of participants will be followed at different, partly overlapping ages (e.g., at the age of 10, 11, and 12 years). A third group from 12 – 14 yrs., and so on. This way a lengthy period can be covered by a relatively short period of data collection. To monitor development closely, intervals between assessments should be no longer than one year. In such a roof-tile design, the focus will be on processes of change instead of describing steady states at different ages as is the case in cross-sectional studies.

Apart from the analysis of thinking-aloud protocols, there are several other methods to assess metacognitive skills, either on-line or off-line (see Chapter 1, section 1.6). Using more than one method in future research will make it possible to cross-validate and complement a particular method with another one (Veenman, in press). A multi-method design will enable the assessment of metacognitive skills in a more fine-grained way. For example in text studying, eye tracking could be added to thinking aloud (Kinnunen & Vauras, 1995). This way, navigating through the text can be registered as a monitoring activity without verbalizations of the student.

In the present study, stabilization in growth took place in the same period that metacognitive skills became fully general. These two changes in development were considered and interpreted as related developmental processes. This study could not establish whether the concurrence of the two changes was coincidental or crucial for 14-15 yr. olds. Future research with more participants performing widely varying tasks over a longer period of time could give more insight whether the two concurrent developments found at the age of 15 yrs. can be replicated as a stable pattern, or whether the concurrence was coincidental. Moreover, following students over a period from the age of 8 till 25 years could establish whether more periods of intermittent growth concur with a transformation process of generalizing metacognitive skills. If metacognitive skills indeed initially set out on separate islands (Veenman & Spaans, 2005) and become fully general during development, there should be at least one period prior to the age of 12 yrs. where intermittent growth and generalization concur. Especially for the educational field, it would be relevant if future research would address this issue again.

7.5 Final remark

In Chapter 2 (section 2.1.2), the question was asked whether metacognition could be reduced to cognition (Slife et al., 1985). This thesis has shown that the answer must be in the negative. Metacognition has its own contribution to learning performance and its own developmental trajectory. Because not all components of metacognitive skillfulness develop at the same time or at the same pace, it is important that teachers foster the right components at the right time during development. By doing so, educators can have a valuable contribution to make the developmental trajectory of students' metacognitive skillfulness a less bumpy one.