Safe-Guarding Cognitive Access to Diabetes Self-Management as Abilities Decline With Age

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People's minds, bodies, conditions and circumstances change with age. Two predictable changes make diabetes self-management (DSM) increasingly difficult over the life course. People's cognitive abilities slowly decline with advancing age, while their chronic conditions demand more complex management and decision-making. The result is a slow-growing cognitive mismatch that makes it more difficult to manage one's diabetes. If not recognized, the mismatch can eventually put effective DSM out of a person's cognitive reach.

International surveys of adult literacy have examined person-job skills mismatch. They help us by detailing why some common everyday tasks demand more cognitive work than others and, thus, why DSM's many and varied demands can quickly overwhelm individuals with low or declining ability.

Frequent Mismatch Between People's Abilities and the Cognitive Demands of Everyday Tasks

Literacy is a capacity for using written information in any form to carry out a wide variety of everyday tasks. Definitions commonly refer to the broad thinking skills needed to use that information: "ability to identify, understand, interpret, create, communicate and compute" (1).

Table 1 gives a concrete sense why this general information processing capacity is critical to learning and managing self care. It lists sample items for five levels of task difficulty on the major literacy surveys, the percentage of Canadian adults functioning at each level and the type of instruction that most benefits people at each proficiency level. Results are from the survey's document scale, but its prose and numerical scales show the same pattern because all are highly correlated.

Nearly half of Canadian adults function at proficiency Levels 1 or 2 – the two lowest. This mirrors the pattern in other survey nations, including the United States and Australia (2). At Level 1, one in five (21.5 per cent [%]) Canadian adults is routinely capable (has an 80% chance) of correctly performing only the simplest tasks, such as totalling a bank deposit entry. The 27.1% of adults who are proficient at Level 2 can carry out tasks that require locating and coordinating two pieces of information, not just one, as long

Table 1: Cognitive difficulty of everyday tasks and per cent (%) of Canadian adults who peak at each level on the International Adult Literacy and Skills Survey (IALSS) document scale, ages 16 and older

Difficulty level	Sample literacy tasks at this difficulty level*	Adults peaking at this task difficulty level		
		%†	Processing skills‡	Training potential§
5	Use calculator to determine cost of carpet for a room Use table of information to compare two credit cards	17.9	Command of higher order processing	Can gather, infer information and patterns on own
4	Use eligibility pamphlet to calculate government benefits Explain difference between two types of employee benefits			Learn well in college format
3	Calculate miles per gallon from mileage record chart Write brief letter explaining error on credit card bill	33.5	Minimum for coping	Mastery learning with written materials and hands-on experience
2	Determine difference in price between two show tickets Locate intersection on a street map	27.1	Weak	Very explicit, structured, hands-on instruction
1	Total a bank deposit entry Locate expiration date on driver's license	21.5	Very poor	Very slow, simple, concrete, step-by-step, one-on-one instruction

*Sample tasks are from the 1993 National Adult Literacy Survey (6). The IALSS adopted its design and many of its items.
†Refer to reference 7; ‡Refer to reference 8; §Refer to reference 9.

Table 2: The higher-order cognitive processing required for optimal diabetes self-management (DSM)

Job of DSM
Purpose: • Keep diabetes under daily control in the often changing and unpredictable circumstances of everyday life. Goals: • Near term: Keep blood glucose (BG) within normal limits. • Long term: Avoid complications and maintain quality of life. Major duties: • Coordinate activities that influence BG (food, medication, physical activity). • Anticipate effects on BG of those activities and their relative timing. • Recognize symptoms indicating that BG is too low or too high. • Adjust food, medicine, physical activity (as needed) to maintain or regain optimal BG. • Obtain BG data from glucose meter or continuous glucose monitor to determine if BG is trending to hypo- or hyperglycemia. • Determine timing and type of corrective action when BG levels are too low (glucose tablets, glucagon, emergency medical care). • Detect and seek treatment for complications of elevated BG levels (vision changes, neuropathies, foot ulcers). • Plan ahead for the unexpected and unpredictable (delayed meals, delayed or missed medication). • Adjust DSM for other influences on BG (infection, emotional stress, insufficient or poor quality sleep). • Coordinate DSM with other self-care regimens (comorbidities, polypharmacy). • Manage conflicting demands on time and behaviour (DSM, family, work). • Update DSM skills and knowledge, as needed (changes in technology, medication, impairments, comorbidities).

as the task is made explicit ("find the difference" between two numbers) and requires only low-level inferences (finding a difference means to subtract).

Individuals who function at Levels 1 or 2 are at a great disadvantage because proficiency at Level 3 is the "minimum for coping with the demands of everyday life and work in a complex, advanced society." Individuals at Level 1 can master unfamiliar tasks beyond Level 1, but will require one-on-one instruction that proceeds slowly, in small steps, with lots of repetition and hands-on practice. In contrast, the 17.1% of Canadian adults who are proficient at the most difficult literacy tasks (Levels 4 and 5) can often grasp and apply highly complex information on their own.

Cognitive Mismatch Grows as People's Abilities Decline With Age

Figure 1 shows how functional literacy trends over the life course: it rises into the 30s, declines slowly into the mid-50s and falls faster with advancing age. Beyond age 65, 87% of adults function below Level 3 and 57% below Level 2, making Level 1 document proficiency the norm among older Canadians. One in five of these older adults reports a diagnosis of diabetes and they account for half of all cases (3).

Indicators of fluid intelligence, such as processing speed and working memory, follow the same downward trajectory, causing learning, reasoning and problem solving to falter and fail increasingly often. Indicators of crystallized intelligence, such as vocabulary and general knowledge (the fruits of intact fluid intelligence earlier in life), generally escape decline until old age. They no longer represent current capacities for information processing, however, so they can disguise declines in the higher order thinking skills so necessary for "coping with the demands of everyday life." As skills decline, individuals become less able to adhere to their treatment and self-care plans. They make more errors and risk hospitalization for severe hypo- or hyperglycemia.

Cognitive Mismatch in DSM

To reduce errors, we need to know which elements of a task increase its cognitive load and how to spot them. Only then can we strategically select or modify self-care tasks and plans to keep them manageable for an individual.

Cognitive load increases with the complexity of the mental manipulations a task requires to get the work done and done right. It increases, for example, when the individual must identify and integrate more pieces of relevant information, ignore distracting (irrelevant) information, perform more

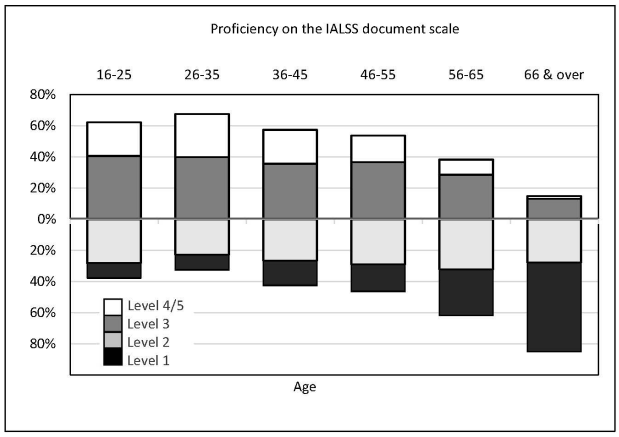

Figure 1: Age-related decline in functional literacy among Canadian adults on the International Adult Literacy and Skills Survey (IALSS). Reproduced from reference 7.

steps, figure out what step to take next, understand more abstract concepts, draw more difficult inferences ("connect the dots") and evaluate a result. Tasks also become more difficult when not all information is provided and not all steps are spelled out, instructions are missing or confusing, the situation is ambiguous or changing, the tasks or tools are unfamiliar and the person has to work around sensory or motor deficits when performing them.

But DSM is more than the sum of its parts. Like other jobs, its biggest challenge lies in selecting, sequencing and coordinating its parts to achieve its purpose. Table 2 shows why managing diabetes can never be mechanical, like following a recipe. It is relentless in requiring judgment, reasoning and problem solving.

Strategy for Reducing Cognitive Mismatch and the Hazards it Creates

Cognitive overload makes it impossible to self-manage effectively. Worse, it increases the odds of dangerous mistakes, such as injecting the wrong amount or type of insulin. Bringing a regimen within cognitive reach requires limiting the number, variety and degree of coordination among DSM tasks until the individual can demonstrate mastery of the regimen. Patient safety also requires eliminating or enlisting helpers for any task that invites calamitous errors (sliding-scale insulin dosing for the frail elderly).

The first prerequisite for reducing cognitive mismatch is to identify what adds to a task's complexity. Supplemental Table 1 illustrates a technique called task analysis that exposes the easily overlooked cognitive hurdles in a seemingly simple use of nutrition labels. It also shows, as with insulin injection, what must not be done. If the individual finds a task too difficult or does it incorrectly, diagnose where in the process their performance broke down. Did they miss a step? Did they eat after taking their medication?

The second prerequisite is recognizing the cognitive demands of instruction itself. Good teaching orders learning by the complexity of the concepts and mental operations to be mastered. Supplemental Figure 1 illustrates how diabetes professionals can use Bloom's taxonomy of cognitive learning objectives (4) to do that. Good instruction also limits its cognitive demands to those intrinsic to learning the material by introducing it clearly, contextualized and logically organized, and by anticipating common misconceptions and errors that impede learning (5). It requires mastery at each level before moving to the next, re-teaching the individual (as necessary) to achieve it. There is no mental test for assessing the normal range of cognitive capacity in a quick, nonthreatening manner, nor is one needed. An individual's errors in self-care pinpoint where to better fit plans and instructions to their needs.

Supplementary information: For additional tables and figures, please click here.

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Instructor's task: Use this label to help an individual master using nutrition labels to plan a meal (breakfast) with the recommended amount of carbohydrate.

Nutrition label

Nutrition Facts / Valeur nutritive
Serving Size 1 cup / Portion 1 tasse
Servings Per Container 10 / Portions par contenant 10

Amount / Teneur	Cereal / Céréale	Cereal w/milk† / Céréales avec du lait†
Calories / Calories	190	250
	% Daily Value / % valeur quotidienne	
Fat / Lipides 4 g*	6 %	8 %
Saturated / saturés 1.5 g + Trans / trans 0 g	8 %	13 %
Cholesterol / Cholestérol 0 mg		
Sodium / Sodium 190 mg	8 %	11 %
Carbohydrate / Glucides 39 g	13 %	15 %
Fibre / Fibres 6 g	24 %	24 %
Sugars / Sucres 11 g		
Protein / Protéines 4 g		
Vitamin A / Vitamine A	0 %	6 %
Vitamin C / Vitamine C	0 %	2 %
Calcium / Calcium	2 %	15 %
Iron / Fer	8 %	8 %

* Amount in Cereal / Teneur de Céréale
† Cereal w/milk adds 60 Calories, 1 g Fat (1 g Saturated), 10 mg Cholesterol, 70 mg Sodium, 7 g Carbohydrate (6 g Sugars), 5 g Protein. / Céréales avec du lait ajoute 60 Calories, 1 g Lipides (1 g saturés), 10 mg Cholestérol, 70 mg Sodium, 7 g Glucides (6 g Sucres), 5 g Protéines.

Action verbs	Objectives: individual must show mastery of each
1. Remember	
Recognize, recall, identify	State the amount of carbohydrate recommended for your breakfast (in grams) Name all ingredients on the label that contain carbohydrate (cereal, milk) If adding other items to meal, name the ones that do (fruit) and do not contain carbohydrate (black coffee) Identify foods that might not have nutrition labels
2. Understand	
Paraphrase, summarize, compare, infer	Explain why the entries for carbohydrate and serving size are important Infer that this label's entry for carbohydrate does not include the carbohydrate in milk Explain how to find the carbohydrate content of unlabelled foods
3. Apply	
Apply a procedure to carry out a task	Locate all entries on the label relevant to counting carbohydrate • Serving size (1 cup) • Servings per container (10) • Carbohydrate for cereal (39g) • Carbohydrate for milk (7g, in footnote†) Calculate carbohydrate in foods added to the meal Calculate total grams carbohydrate to be consumed
4. Analyze	
Distinguish, focus, select, integrate, coordinate	Integrate several pieces of information (the two % daily values for carbohydrate) to infer that the label gives carbohydrate grams for milk too, and probably near the column "cereal /w milk" Select correct arithmetic operations to calculate carbohydrate content of each food, plus their total • x cups of cereal • the milk for it (Note that the label gives no serving size for milk) • other foods in the meal, labelled or not
5. Evaluate	
Check, monitor, detect inconsistencies, judge effectiveness	Evaluate whether • the intended meal contains the recommended amount of carbohydrate (in grams) • other circumstances require consuming fewer or more grams of carbohydrate (high or low blood glucose, anticipated physical activity)
6. Create	
Hypothesize, plan, invent, devise, design	Plan snack or another meal with recommended amount of carbohydrate Create daily menus with recommended amounts of carbohydrate and other nutrients

Supplemental Figure 1: Example of instructor using Bloom's taxonomy of educational objectives (cognitive domain) to sequence instruction by complexity of information processing.

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Supplemental Table 1: Sample task analysis of label use that illustrates how to uncover a task's nonobvious demands for information processing

Self-management task	
Here is the nutrition label for your snack later today. You have diabetes, so you want to eat the right amount of carbohydrate. Assume for now that it is 15 grams (g) for a snack. Use this label to figure out how much of the product you should eat to get that amount.	
A. Steps in this task	
1. How much carbohydrate is in one serving?	
a. Recall that you need to locate an entry for carbohydrate.	
b. Cycle through the information on the label to find the correct entry for carbohydrate: total carbohydrate.	
c. Ignore the entries for total sugar and added sugar. These sources of carbohydrate are included in total carbohydrate, as indicated by their indentation.	
d. Ignore the entry for calories. It is not relevant to your task.	
e. Ignore all the other nutrients, whether healthy for you (protein, vitamins and minerals) or not (fat, cholesterol, sodium). They are not relevant to your task.	
f. Recall that carbohydrate is measured in g.	
g. Locate the number of grams listed for total carbohydrate (here, 37g).	
h. Ignore the other number after total carbohydrate – 13 - for % daily value. It is not relevant.	
i. Recall that 37g of total carbohydrate is for only one serving and that the package may contain more than one serving.	
2. How much of the product in the package counts as one serving?	
a. Understand that one serving is a standard amount, not the amount that you might think of as a serving.	
b. Cycle again through the array of information to locate entries for number or size of servings in the package.	
c. Recognize that two entries near the top are relevant: 8 servings per container and serving size 2/3 cup (55g).	
d. Understand that in the entry for serving size, 2/3 means two-thirds and that a cup refers to a standard measuring cup, neither a teacup nor a mug.	

Supplemental Table 1 (cont'd): Sample task analysis of label use that illustrates how to uncover a task's nonobvious demands for information processing	
e. Understand that the parentheses - ( ) - around 55g for serving size means that this quantity provides a second way to measure one serving.	
f. Understand that this second way of measuring serving size, 55g, is for the total weight of one serving, not the g (grams) of total carbohydrate in it (here, 37).	
3. How much of the package will give you the right amount of carbohydrate?	
a. Recall that 15g is the amount of carbohydrate allowed for a snack.	
b. Determine whether one serving gives you the right amount, too much or too little carbohydrate. (In this case it is too much because 37g is more than twice 15, so you can't eat more than half a serving.)	
c. Select the correct numbers to calculate how much of the product constitutes half a serving. There are three options: number of servings (8), serving size by volume (2/3 cup) and serving size by weight (55g).	
d. If you opt to use number of servings (8), select the appropriate arithmetic operation(s) to calculate how much of the package you can eat. If one snack is roughly half a serving, then one serving equals two snacks. Multiply 2 (snacks in a serving) by 8 (number of servings) to get the number of snacks in the packet: 16. Divide the packet into 16 parts and take one or estimate in some other way how much to take out for 1/16 of the package.	
e. If you opt instead to use serving size 2/3 cup, select the appropriate arithmetic operation(s) to calculate how much of the packet you can eat. If one snack is half a serving, divide 2/3 cup (one serving) by 2 (number of snacks in a serving) to get half a serving (1/3 cup). Use a standard measuring cup to remove 1/3 cup of the packet's contents.	
f. If you opt to use serving size 55g, select the appropriate arithmetic operation(s) to calculate how much of the packet you can eat. If one snack is about half that by weight, use a kitchen scale to take about 27g out of the package. Since 55g of snack contains 37g carbohydrate, you will be taking out half a serving (which will be about 18g carbohydrate).	
B. Elements of information processing that add to a task's complexity (the number-letter combinations refer to steps above)	
1abf, 3a.	Requires technical knowledge specific to diabetes: nutrient(s) that affect blood glucose level, that their amounts are measured in number of grams and the amount recommended for a snack.
1c, 2adef.	Requires technical knowledge not specific to diabetes: abbreviations (g, mg, mcg), mathematical symbols (%, /), writing conventions (subcategories are indented) and measurement conventions (cup, serving size).
1bcde.	Nutrient entries are for abstract categories (fat, carbohydrate, sugars).
1c.	Some nutrient entries are subcategories of others: dietary fiber and total sugar, of total carbohydrate.
1cdh.	The label contains irrelevant entries that resemble or are adjacent to relevant ones.
1b, 2b.	Cycle twice through an array of information to locate two different and nonadjacent types of information.
3a.	Label does not provide all the information required to calculate recommended amount of snack to eat.
3c.	Select appropriate data for arithmetic calculations.
3bdef.	Select appropriate arithmetic operation(s) to calculate an answer.
3def.	Choice of arithmetic operation(s) is contingent on type of data chosen to calculate the answer: number, weight or volume of one serving.
3bdef.	The arithmetic operations require multiplication or division, which are harder than addition or subtraction.
3e.	The arithmetic operations require manipulating fractions or decimals, which is harder than whole numbers.

Source of label: U.S. Food and Drug Administration. Changes to the Nutrition Facts Label. Available at: www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm. Accessed Mar. 7, 2021.