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A passive assessment of homecare need with a Rasch model

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ABSTRACT

This article proposes a new way of passively assessing homecare need for older people living at home. The main advantage is to provide a precise measure with a limited effort for the caregivers. Research proposition is based on a Rasch model that uses available daily activities of care, which are performed by the professional caregivers. The proposed approach follows the idea of a precision and personalized care where the collected data provide a dedicated measure for the recipient's homecare needs. Then from the latter, the recipient's autonomy can be approached. Data from 531 recipients were used. They are collected by a French company providing a Cloud service hosting different homecare services. The proposed Rasch model aims at completing the available geriatric level of autonomy (GIR) in order to have a precise and continuous evaluation of the autonomy. No significant misfit appeared on the considered items of the Rasch model. Thus, a satisfying Rasch model is proposed for the different GIR levels showing a consistent relation with this widespread scale. The proposed assessment enables a continuous evaluation of the evolution of the loss of autonomy for each recipient through the assessment of each recipient's homecare need. Moreover, it provides a wide range of uses and is a good starting point to bring forth new indicators towards a precision care. Indeed, our assessment is more responsive but dependent on the GIR scale. For example, a changepoint detection on a recipient's need curve can open discussions amongst the various stakeholders and thus new means of care can be submitted regarding the evolution of autonomy. This approach's purpose is to help the stakeholders, especially the professional caregivers, to adapt their action plan. It addresses the complexity of having better indicators for the caregiving needs of older persons living at home.

Keywords: Home caregiving, Rasch model, older people, passive assessment, ethical reasoning.

1. INTRODUCTION

As the number of older people increase in Europe, aging in place appears as a beneficial compromise regarding quality of life [1] or maintaining social networks [2]. In addition, people facing a loss of autonomy generally prefer staying at their home. In France a public aid is granted by the state. This grant is conditioned by the recipient's level of autonomy : the more dependent the applicant, the more aid granted (with another condition on the income of the applicant). This public aid, called Custom Autonomy Allocation (APA in French), aims to assist recipients to pay the expenses of home care. Note that

there is also the possibility to live in a nursing home in which case the previous aid is completed with others. The degree of loss of autonomy of the applicant is measured with the Autonomie Gérontologie Groupe Iso Ressources (AGGIR) grid [3].

The AGGIR grid classifies the applicant in one of six groups named Groupes Iso-Ressource (GIR). It measures the person's capacity from 10 discriminatory activities : communication, orientation (time and space), toilet, dressing, eating, elimination, transferring, indoor moving, outdoor moving, using a remote communication. There are 7 more activities rated but not taken into account for the GIR computation. Their lack is debatable as some authors argue they should be taken into account [4]. From the above mentioned activities, an algorithm is applied to classify the applicant. Each one of the 6 GIR groups corresponds to a specific level of autonomy. The highest level of autonomy is the GIR 6 and it decreases until GIR 1. In this way, the GIR 1 group gathers persons confined to bed or chair with potential impaired mental functions or persons at the end of their life.

Assessments are essential in home care field as they give important information about someone's state in a given dimension. The assessed dimension is usually the functional ability (or autonomy) [5] but it can also be a psychological aspect [6]. Most of the time, activities of daily living are used to evaluate one's autonomy. To do so, several scales exist such as the so-called Activities of Daily Living (ADL) [7] and its extensions like Instrumental Activities of Daily Living (IADL) [8] which adds more complex activities that are essential to live independently, for instance cooking or shopping. Some studies have addressed ADL assessment with a Rasch model [9], [10]. However, to our knowledge no studies tackle the passive assessment of someone's need for help. The passive assessment does not require an extra time for the professional caregivers. For this reason, this can be considered as an assessment without assessor.

The main goal with the proposed passive assessment of a recipient's homecare need is to construct a more responsive tool for monitoring recipients' state. In non-passive assessments, the response to an event can be too late. Yet, the speed of adaptation is essential in homecare. The important point is not really the assessment itself, but the time series of assessments on which changepoint detection methods can be applied afterwards. So it is more the change and the curve's global behavior that should warn about the recipient's state than the intrinsic value. Once homecare need values are available for a

recipient, the professional can use it to change and adapt the action plan. Then, the assessment proposes to modify the action plan : it would invite the different stakeholders (recipient, geriatric physician, caregivers, ...) to evaluate the homecare need regarding new indicators through an ethical reasoning. Thus, the proposed indicators are statistics results that address the complexity of computing the value for the recipient. It conforms to the complexity of an ethical decision since the statistics results must be discussed and evaluated through an ethical approach of reasoning. The ethical aspect is guaranteed by taking into account the opinions of the different stakeholders. It can be a democratic approach (a vote system), an evidential approach (decision matrix of criteria and outcomes) or other existing approaches as described in [11].

Instead of having a specific time to assess the recipient, the suggestion is to use collected data about what is done at his home by professional caregivers, allowing a continuous monitoring. In this presentation, it should be stressed that there is still a professional intervention but it is not about the assessment itself : the professional intervenes only to help the recipient. In this study only people already facing a loss of autonomy characterized by a GIR from 1 to 4 are considered. Hence, people classified in GIR 5 or 6 are excluded, i.e., people who are regarded sufficiently autonomous by the French administration.

Finally, this study conforms to the French law (Jarde law) and is not considered as a research involving the humans. It is a research having a public interest that is exclusively conducted from statistics about social personal data. However, the results could be reused for conducted medical studies related to geriatric. Moreover, SIPAD has habilitation for hosting those data and can perform statistical analysis from the available data such as proposed in the present paper.

2. THE MODEL

Tasks considered

The data come from carried out tasks at a recipient's home by professional caregivers and are collected by a French company named SIPAD, which provides a SaaS application for home care professionals. A total of 149 tasks is available. Each one of them is labelled as one of the following 15 categories:

1. Mobility aid (help for moving in and out of bed or chair, walking, etc.)
2. Personal hygiene aid
3. Cooking and feeding aid
4. Indoor activities (chatting, reading, playing, etc.)
5. Outdoor activities (shopping, going to appointment, going to museum, etc.)
6. Housekeeping for kitchen (wash dishes, wash floor, tidying dishes, etc.)
7. Housekeeping for sanitary (cleaning toilets, wash the floor, etc.)
8. Housekeeping for bedroom (changing of bedding, ventilate the room, etc.)
9. Global housekeeping (vacuuming, wash the floors, etc.)
10. Gardening
11. Laundry care
12. Administrative support
13. Medication intake support
14. Pet support (going to the groomer, feeding, etc.)

15. Logistical tasks (switching heater on, changing a bulb, etc.)

Some tasks have been merged for practical purposes. For instance the tasks "I prepared the breakfast", "I prepared the lunch" and "I prepared the dinner" were merged in a unique task named "I prepared a meal". The tasks are conjugated in the first person singular because it represents the professional's point of view. The data are represented as a matrix with columns giving the name of the task and the row indicating a recipient and a date. In this matrix, if the tasks has been carried out by the professional then it is labeled as 1 in the corresponding coordinates and 0 otherwise. It should be pointed out that only SIPAD Cloud data associated with the GIR level were used.

The Rasch model

To model the considered data, a dichotomous Rasch model was used. The Rasch model allows to measure one's ability on an unobserved dimension (called the latent trait) from observed responses to a given questionnaire. The questionnaire is made of qualitative items. For each individual and each item, a probability of success is given by the Rasch model. In details, the Rasch model gives :

$$\mathbb{P}(X_{ij} = 1 | \theta_i, \beta_j) = \frac{e^{\theta_i - \beta_j}}{1 + e^{\theta_i - \beta_j}} \quad (1)$$

With $i = 1, \dots, N$ and $j = 1, \dots, n$. The response of the i -th individual on the j -th item is X_{ij} , $\theta_i \in \mathbb{R}$ is the respondent's ability and $\beta_j \in R$ is the item's difficulty.

From the $N \times n$ matrix of responses, the model computes raw scores r_i , i.e. the sum of scores on all items for a given individual. Those raw scores are then used to estimate the difficulty's parameters, i.e., to compute from the data a value for the unknown parameters. The latter are used to estimate the abilities with a statistical well-known plug-in procedure. To estimate difficulties, several procedures exist. One of these uses the marginal likelihood [12] and is performed in the R package *mirt* [13]. The idea is to maximize the marginal likelihood, described in the Eq. (2) :

$$\mathcal{L}_{marginal} = \prod_{i=1}^N \int_{-\infty}^{\infty} \prod_{j=1}^n g(\theta_i) \mathbb{P}(X_{ij} = x_{ij} | \theta_i, \beta_j) d\theta_i \quad (2)$$

Where $g(\cdot)$ represents the distribution of the latent ability, generally set as a normal distribution. Alternatively, it can be built from the empirical distribution. The integral is computed with a Gauss-Hermite quadrature while the maximization is performed with the Newton-Raphson algorithm. Likewise, there are several procedures to estimate abilities.

The important aspect of Rasch model is that it allows to compare on the same scale items' difficulties and respondents' abilities : this is the logit scale. From this common scale, the examinee can determine for a given individual's ability, which items are more likely to be passed by the individual. Indeed, the higher the ability than the difficulty, the more likely the individual is to give a correct answer.

In this work context, the interpretation of θ_i and β_j must be adapted. In a general Rasch model, the coefficient θ_i represents the i person's ability. The higher its value, the more likely the

person to success on a given item. In addition, generally speaking, the data is a $N \times n$ matrix whose element at coordinates (i, j) is 1 if the individual i has succeeded the item j . Nevertheless, in this context the data are reversed. Indeed, the data are coded with 1s when individuals did not make the task by themselves, because 1s correspond to what have been done by professional caregivers. Hence, the interpretation of parameters θ_i cannot be the recipient's ability, apart from the fact that "ability" could lead to confusion in home care context. Instead, we suggest that it represents the recipient's need. In this way, we do not assess a person's ability, which is provided by the AGGIR grid. Instead we assess a person's needs. Again, the proposed assessment is strictly a social measure rather than a medical one. The higher the value, the more likely the professional will carry out the task : this is consistent with the interpretation of θ_i of a Rasch model.

Similarly with the β_j coefficients, representing the item's difficulty, we cannot use this interpretation. Indeed, the difficulty of a given task is subjective: a task's difficulty depends on the recipient's disorders. For instance, cleaning the floor is substantially harder for someone with arthritis than for someone without it. Hence, using the word "difficulty" implies that the people must be homogenous from an ability point of view, which is not the case here. For those reasons we suggest using the word "cadence" for the coefficient $-\beta_j$ (with emphasis on the minus). Seeing β_j as difficulty in a Rasch model means that higher the coefficient, the less likely to succeed the item. In our context, the higher $-\beta_j$ i.e. the cadence, the more likely the professional to carry out the task, so our suggestion "cadence" is consistent with the general interpretation in a Rasch model.

From the estimations of both θ_i and β_j , for all i and j , one can deduce which tasks are expected to be carried out by the professional. Indeed, in a Rasch model context, when the individual's parameter is superior to an item's parameters then the individual is capable of succeeding the aforementioned item. In our context, this allows to predict from the individuals' parameters and tasks' parameters, which tasks are expected for each recipient according to the model. Then one can compare, for a given recipient at a given time, the difference between the expected tasks and those actually carried out. Of course the model's quality has an influence on the previous difference. Therefore, poor quality makes a model unusable. But if it is of acceptable or good quality and is consistent with the context then it is usable and of great help for the professional's activity. In addition, if a degradation (respectively an improvement) of the recipient's theta value occurs, it is possible to determine which new tasks will henceforth be expected (resp. will no longer be expected to be carried out). In this way, a prediction could be possible to monitor the recipient's needs. Note that in our context, a degradation of the θ_i value means an increase, because the higher θ_i , the higher the need for help.

Metrics of the model

The Rasch model holds with several assumptions that must be checked for validity. One assumption is the unidimensionality, which basically means that all items from the submitted questionnaire measure a single value, namely the latent trait. In other words, the constructed latent trait explains the observed variance in the data. This assumption can be checked post hoc with a Principal Component Analysis (PCA) of the standardized residuals. The Rasch model should explain more than 50% of

the total variance and the largest second dimension should have an eigenvalue less than 2.0 [14]. If the second dimension has an eigenvalue superior to 2 then this dimension has the strength of as many items as the rounding of the eigenvalue [14]. For instance if the second dimension has an eigenvalue equal to 3.7 then it approximately worths 4 items. Another measure of the unidimensionality is the Cronbach's alpha, which measures the internal consistency or the reliability [15]. This statistical measure indicates whether the items measure the same trait. A value of .7 is considered "good" while a value inferior to .5 is usually considered as unacceptable [16]. Yet, the Cronbach's alpha is not a statistical hypothesis test but only a quantitative measure giving an indication.

Another important assumption is the local independence. Although this notion is more subtle, this may be seen as the independence between the responses of an individual [17]. If there is local dependence then it acts as an explanatory factor. To be more precise, the local dependence is a form of violating unidimensionality [18]. So the local independence assumption is checked by the same procedures as for unidimensionality and is harder to detect. In addition, goodness-of-fit measures may be examined in order to evaluate its quality. The most used measures are the infit/outfit mean square statistics. They are used for item fit as well as person fit and global fit. An item is misfitting when the infit/outfit mean square value is outside the range [0.7, 1.3] [19]. Note that standardized versions of infit/outfit exist. Those follow a standardized normal distribution, even though the use of infit/outfit in the analysis of fit is controversial [20]. Outfit measure the mismatch between model and data. Moreover it is more sensitive to the responses of individuals for whom a given item is too easy or too difficult. In other words, the outfit statistic is sensitive to outliers. That's why the infit value is introduced. The infit statistic is a measure of residuals weighted by its variance so that outliers are less important in the computation. For more details about residuals in a Rasch model, the reader should refer to [21]. The global infit/outfit measure is the average of all those measures.

The Andersen's likelihood ratio test provides an overall goodness-of-fit statistic and an associated p-value that represents the probability of wrongly rejecting the null hypothesis. This likelihood ratio test splits the data into several sub-groups and computes the ratio of the total likelihood over the product of the sub-likelihoods [22]. The null hypothesis assumes the ratio is equal to 1, i.e., there is no difference between groups. The constructed test statistic is chi-squared distributed. Last, a Differential Item Functioning (DIF) procedure was performed to determine whether items' difficulties vary across groups [23]. If so, then the Rasch model is misfitting as it misses an explanatory factor. For instance, recipients classified as GIR 1 may have a lower difficulty for some items than recipients classified as GIR 4. Therefore, the latter would have a lower probability of having the item performed because in the present case the "success" is associated with the completion of the task by the professional caregiver. DIF occurs on an item when there is a difference of more than 0.5 logits between groups [24].

3. RESULTS

All computations were run on a computer with an Intel Core i7-10510U CPU @ 1.80GHz, 16 Go of RAM, running Windows 11 with the R software [25]. The Rasch model's parameters

were estimated (i.e. computing an approximation for the parameters from the data) using the `mirt` package [13]. A total of 510 observations were used to the general model's estimations. In details, there were 15 recipients facing a GIR value equals to 1, 138 recipients of GIR 2, 118 of GIR 3 and 260 of GIR 4. The gender was not known and is not involved in this study. Likewise, the marital status, the income, the (former) profession and medical conditions are not involved. The age could have been added but in return the data would have been half as many. A general Rasch model was estimated using all the data, then a Rasch model per GIR level using only data from the given GIR level were estimated. In that respect, five Rasch models were estimated. Originally, the task about shopping was included but it appeared that this task had been made too many few times for people classified in GIR 1 to be included in the models. Therefore, this task was excluded of the study. Eventually, there were $n = 13$ tasks included in the models.

Table 1 : Values of interest for all the five Rasch models

	AIC	BIC	Log-likelihood	α	λ_1
All GIR	7475.97	8043.38	-3603.98	0.6	3.40
GIR 1	488.88	583.76	-110.44	0.78	4.11
GIR 2	2383.31	2775.56	-1057.66	0.6	3.48
GIR 3	1995.72	2366.99	-863.86	0.6	3.52
GIR 4	3402.22	3879.35	-1567.11	0.55	3.22

All values of Aikake Information Criterion (AIC), Bayesian Information Criterion (BIC), Loglikelihood, Cronbach's alpha, first eigenvalue of standardized residuals noted λ_1 for all the five Rasch models are resumed in the Table 1. All Cronbach's alpha excepted the one from GIR 1 model are < 0.7 . In addition, all first eigenvalues of the standardized residuals are > 2 .

Outfit measures (Figure 1) are in the reference range [0.7,1.3] excepted the items "I changed urinary protections", "I helped get dressed", "I helped to take the meal" in the GIR 1 model. This may be explained by the small amount of data in the GIR 1 model. The infit measures are all in the reference range [0.7,1.3] (Figure 2). The goodness-of-fit measures show no particular misfit in all models.

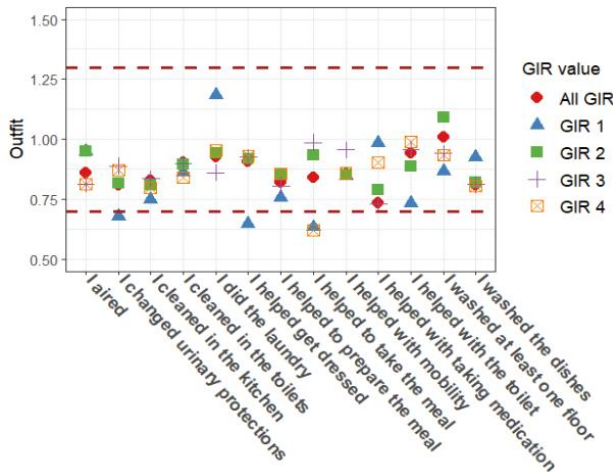


Figure 1 : Outfit values of all models.

The estimated values of $-\beta_j$ for all models are displayed in the Figure 3. DIF occurred on all items excepted on the item "I aired". Therefore this task is carried out without distinction on the GIR level. In other words, professional caregivers air GIR 1's houses as well as GIR 4's ones with no higher probability for one than the other. For some tasks DIF occurred between all groups while on other tasks DIF occurred between only 2 groups. For instance the task "I helped with taking medications" has DIF between all groups taken side by side. It appears that GIR levels are ordered along the β_j axis for most of the tasks. This indicates that, for the concerned tasks, professionals are more likely to carry out the task at GIR 1's home than at GIR 2's home, itself more likely than GIR 3's home and so on. The exceptions are the tasks "I cleaned in the kitchen", "I cleaned in the toilets", "I washed at least one floor". Those are household tasks, more frequently carried out at rather independent recipients' house. This can be explained by the fact that a recipient classified in GIR 1 needs less floor cleaning for he is bedridden and this is not one of the vital tasks. Regarding the "I did the laundry" task, there are two groups in the Figure 3 : GIR 1 and others. So its cadence is higher for GIR 1 than for others.

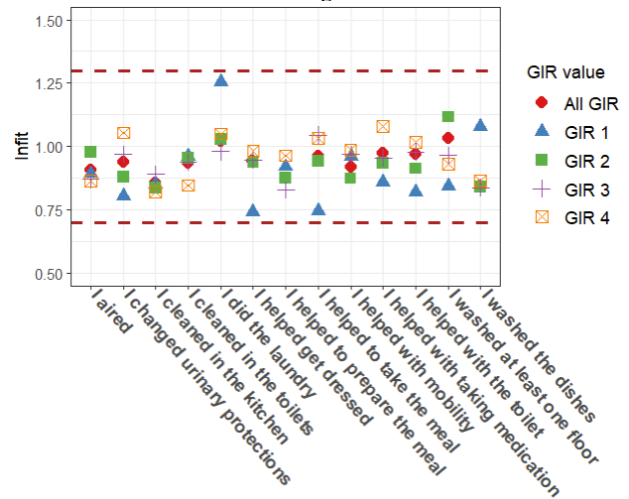


Figure 2 : Infit values of all models.

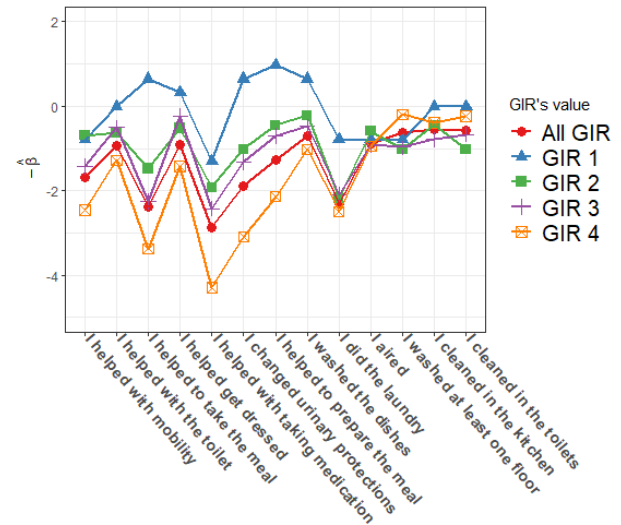


Figure 3 : Estimated values of $-\beta_j$ values for all models. The higher $-\beta_j$, the more likely the professional carried out the task.

Then, for each model, a curve from the estimations of β_j is built. Those curves are the expected total score. For a Rasch model, the expected total score is given by function $T(\theta)$ as described in the Eq. (3) :

$$T(\theta) = \sum_{j=1}^n \frac{e^{\theta-\beta_j}}{1 + e^{\theta-\beta_j}} \quad (3)$$

The function $T(\theta)$ represents the relationship between the raw score and the θ value. All the five total score (one per model) are displayed in the Figure 4.

Using the expected total score curve, it is possible to compute the estimated need from the total score. Thus, by taking all carried out tasks at a recipient's home, one can plot the time series representing the recipient's need and study it. An example of such usage is the Figure 5, from a recipient classified in GIR 4. In this example, it is clear that the recipient has known one steady period with a plateau of need near 1.25 logits around week 37 followed by an increase. This increase broadly stabilized at around week 42 with a need of approximately 3.5 logits. So in this example, the Rasch model gives a new indicator allowing a more practical recipient's monitoring : it appears that this particular recipient has increasing needs. The resulting discussion amongst the stakeholders may then suggest either a re-evaluation of the GIR level or an increase in working time for the professional caregivers. If the GIR level is obsolete and downgraded to GIR 3, the corresponding Rasch model can be used in a continuous monitoring.

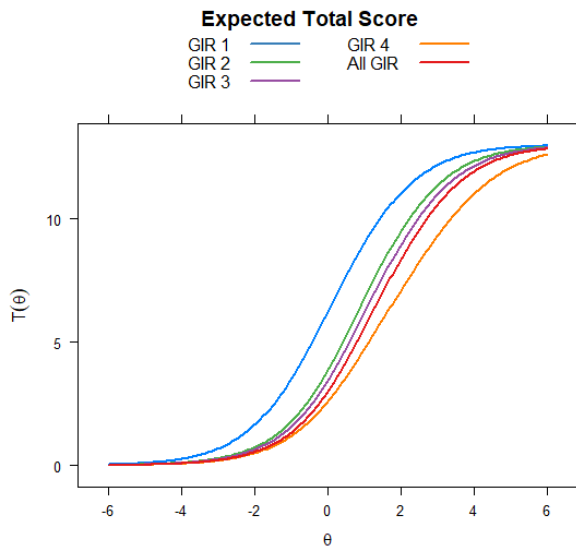


Figure 4 : Expected total score for all five estimated models. This represents the relationship between the raw score (i.e. the sum of the responses over the items) and the estimated θ value. While the first is finite (from 0 to 14) the latter has an infinite range. Note that the curves are ordered according to the GIR level, which means that GIR 1 have, on average, higher probabilities than GIR 2 and so on.

4. DISCUSSION AND CONCLUSION

Despite the small number of people involved, no significant misfit occurred except for the one caused by the GIR, which is

discussed hereafter. From the Rasch models, recipients are passively assessed at each intervention using all carried out tasks by professionals, which are namely social data. The θ_i values allow to monitor recipients for long periods as in the Figure 5. The major added value with the proposed method is to assess recipients without dedicating a specific time, i.e. a passive assessment, thus allowing a greater number of assessments. Moreover the proposed method require no additional background for the professionals because we use only data that are already existing with no direct involvement of the professionals in the assessment excepting when performing the described tasks. In addition, given that this is a legal obligation, data about the carried out tasks are necessarily collected.

On the other hand, the GIR is reassessed on request of the recipient. Therefore, the model can help improve the precision of the GIR value by having more assessments. A corollary of having more assessments is a greater responsiveness in the recipient's monitoring by using changepoint detection methods. For instance, a changepoint detection model has detected three plateaus in the Figure 5. In addition, continuing with the example, the need increase suggests to re-evaluate the recipient's GIR level. That decision may be suggested in an open discussion amongst all stakeholders, based on the passive assessment.

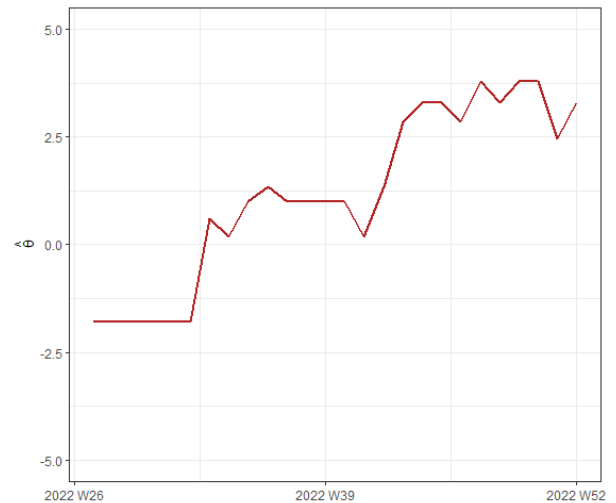


Figure 5 : Example of need's curve for a given recipient with one estimated need per week taking all carried out tasks of the week. There are two plateaus around week 37 and week 42 with a need value around 1.25 logits and 3.5 logits respectively : this is an example of need increase leading to a discussion amongst the stakeholders.

The observed DIF is due to the GIR value. This implies that the GIR is an external factor, having an effect on the estimated values. The DIF justifies the GIR-wise conditioning of Rasch models. The GIR effect is also visible in the Figure 3. One limitation with the present approach is that assessments are conditioned by GIR level : it is only once the GIR is known that it is possible to use our method. The conditioning has two benefits. First, it improves the precision of the GIR value. Indeed, it allows discriminating recipients of the same GIR level who are slightly different. Second, it is consistent with social approach where GIR is evaluated by social workers regarding the public aid. The implication is that the estimated

values of θ_i can only be compared within the same GIR level group. For instance, comparing estimated θ_i values from a GIR 3 with a GIR 4 has no sense in our method, because the models used for the estimations were not the same. Further investigations about the GIR and our assessment must be conducted to study the link between those two quantities, though a beginning link has been found. Low values of the Cronbach's alpha coefficients as well as the PCA's eigenvalues indicate a potential second dimension. In particular with the general model including all GIR values, this is explained by the fact that the second dimension could be the GIR value. For the models conditioned by the GIR value, an explanation may be that in home care, it is common to make a distinction between personal care and household care. In detail, the more the recipient is facing a loss of autonomy, the more the professional is likely to help him in his personal care. So, recipient classified as GIR 4, i.e. a beginning of a loss of autonomy, is more likely to be helped with household care such as cleaning or laundry rather than personal care. In addition, home care workers empirically use this distinction between personal care and household care to detect whether the recipient's autonomy is worsening. Further refinements regarding this distinction could significantly improve the results, notably by splitting the tasks into two categories and then running Rasch models.

Another limitation of this study is the non-inclusion of people classified in GIR 5 or 6 due to a lack of data. To broaden the scope of application and being able to monitor rather independent people, more data must be collected and apply the same method to study whether less dependent people can be monitored the same way. Moreover, the matrix of data where coded as 0 when the professional did not carry out the task. However, there is no information whether it is because the recipient can do it by himself or if it is his caregivers who did it. In other words, one cannot discriminate when the recipient is autonomous in the task from the case when he's helped in the same task by his caregivers. So it is necessary to take into account the help provided by the caregivers.

Finally, future studies would require a research involving the medical context of the recipient. Indeed, research approach proposes raw indicators that could have good meanings in the light of the medical context. This point is outside the present work. But, physicians or epidemiologists could reuse these indicators to address the medical situation of the recipient. In addition, ethical reasoning can reuse the evaluation method to compute value for patient, health evolution or quality of life. Thus, the indicators can improve the democratic decision with a better knowledge of the recipient needs.

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