

User guide on how to annotate freezing of gait from video recordings

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This user guide describes the steps on how to annotate freezing of gait (FOG) episodes from video recordings using the open-source ELAN software.

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Disclaimer:

The ELAN multimedia annotation software is developed by The Language Archive (TLA) of the Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands. As stated by the TLA: *"All Software developed by TLA may be used free of charge (freeware). It is also 'open source': the source code of ELAN can be downloaded from the ELAN download page, the source code of other TLA software is available upon request under the Gnu Public License 2 (in some cases GPL 3)."*

To Cite the use of ELAN please refer to:

ELAN (Version 5.6) [Computer software]. (2018, April 04). Nijmegen: Max Planck Institute for Psycholinguistics. Retrieved from <https://tla.mpi.nl/tools/tla-tools/elan/>



ELAN thus offers a free software solution to standardize the annotation of FOG episodes and calculating the percentage of time spent with FOG (%FOG) during video-recorded assessments in patients with Parkinson's disease (PD) or related disorders.

Here, I describe the steps to install and navigate the ELAN software for this purpose. I also provide a free template (.etf) file containing frequently used annotations to score FOG, which can be implemented into the ELAN software. I conclude this user guide with guidelines on how to standardize the visual scoring of FOG across raters and studies.

Importantly, the virtue of this software is that you can create your own templates according to the task conditions and events that you wish to score. How to do so, is also briefly explained in this user manual. So, although ELAN was initially developed for studying psycholinguistics, it can also be used to score other motor features in PD, as well as other study populations.

Good luck.

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2. Getting started

2.1 - Installation

- Download and install the ELAN software, as well as the user guide and manuals provided by TLA from: <https://tla.mpi.nl/tools/tla-tools/elan/>
- Download the “**FOG_scoring_Template.etf**” file from: morangilat.com

2.2 - Opening a File

- Open the ELAN application
- Go to ‘**File**’ and select ‘**New**’. → To continue working on a project, select ‘**Open**’ and select the “.etf” file that you saved previously.
- In the pop-up window you are asked to add a ‘*Media File*’ and a ‘*Template File*’.
 - Under ‘*Media File*’ select the **video** you wish to score.
 - Under ‘*Template File*’ select “**FOG_scoring_Template.etf**” (or your own template)
- Press ‘**OK**’.

3. The FOG-scoring template

The main screen will now appear, as per **Figure 1**. The video is presented on top and the area to select events and place annotations at the bottom. The red line indicates your current position on the video’s timeline.

Each row is called a “**Tier**” (for example ‘Gait_Task’). The FOG-Scoring template contains four predefined Tiers. It is, however, very easy to add, delete or change any of the Tiers, see *Chapter 7*.

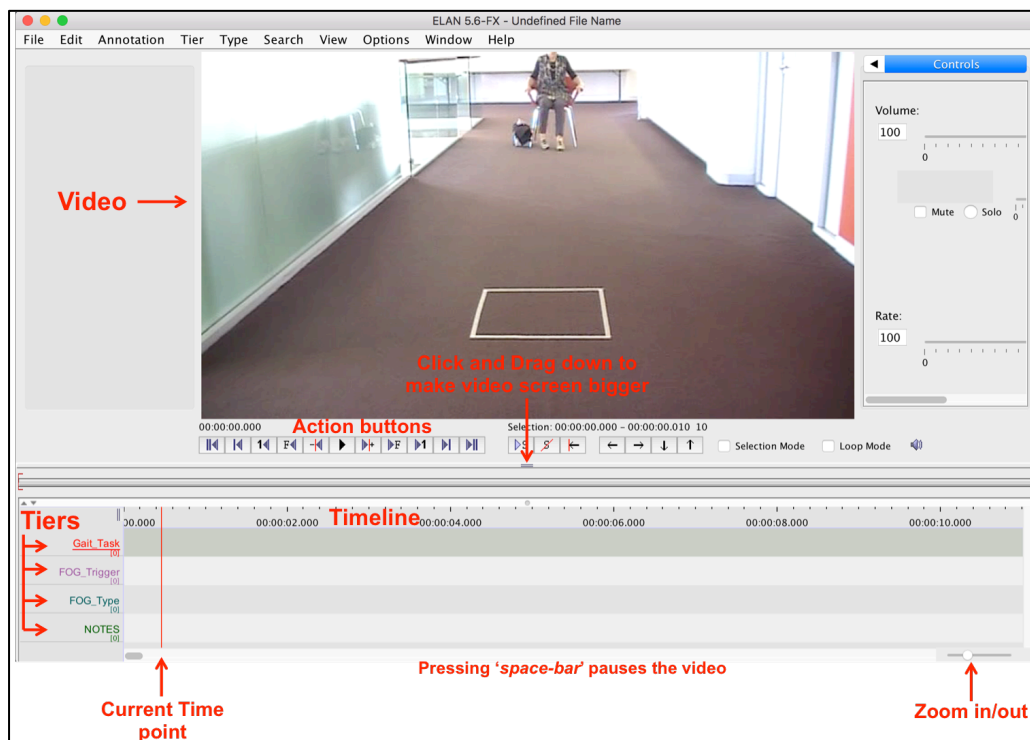


Figure 1: Layout of the FOG Template

See **Tables 1 and 2** for a list of the pre-specified tiers and annotations as provided in the FOG-scoring template.

Table 1: List of pre-specified Tiers

Tier	Description
Gait Task	Frequently used gait tasks to assess Freezing of gait in the clinic. -TUG = Timed up and Go variations, as per: Walton et al. (2017) [1] In short: Participants get up from a chair, walk 5 meters towards a taped square on the floor, perform a certain type of turning condition inside the taped box, return to the chair and sit back down. -360spin = Turning-in-place 360 degrees, as per: Mancini et al. (2017) [2] -FOG Course = FOG provoking walking course, as per: Ziegler et al. (2010) [3]
FOG Trigger	Different situations during which FOG episodes frequently occur in patients with Parkinson's disease, such as turning and doorways.
FOG Type	FOG can be characterized by the leg motion observed during the episode. As per Schaafsma et al. (2003) [4]. -Shuffling = Very small shuffling steps with minimal forward movement; -Trembling = Leg trembling but without effective forward motion; -Akinesia = No observable motion of the leg, despite the intention to walk.
NOTES	Any free text annotations.

Table 2: List of pre-specified annotations per Tier

Tier	Annotation	Description
Gait Task	TUG_180_R	TUG with 180 degrees turn to the right
	TUG_180_L	TUG with 180 degrees turn to the left
	TUG_540_R	TUG with 540 degrees turn to the right
	TUG_540_L	TUG with 540 degrees turn to the left
	TUG_Dual_180_R	TUG with 180 turn to the right while performing a dual task condition
	TUG_Dual_180_L	TUG with 180 turn to the left while performing a dual task condition
	TUG_180_R_Doorway	TUG with a 180 turn to the right and a doorway in the walking course
	TUG_180_L_Doorway	TUG with a 180 turn to the left and a doorway in the walking course
	360spin_R	360 degrees turning-in-place to the right
	360spin_L	360 degrees turning-in-place to the left
	FOG_Course	FOG provoking walking course
	FOG_Course_Dual	FOG provoking walking course with a dual tasking condition
FOG Trigger	FOG	FOG during straight walking in absence of an obvious trigger
	FOG_SH	FOG during the initiation of the first step after stopping
	FOG_Target	FOG in the final steps when approaching a target (e.g. the taped box or chair in a TUG)
	FOG_180_R	FOG during a 180 degrees turn to the right
	FOG_180_L	FOG during a 180 degrees turn to the left
	FOG_360_R	FOG during a 360/540 degrees turn to the right
	FOG_360_L	FOG during a 360/540 degrees turn to the left

	FOG_Doorway	FOG when passing through a doorway or narrow passage
	FOG_Dual	FOG induced due to the performance of a cognitive- or motor dual task
FOG Type	Shuffling	Very small shuffling steps and with minimal forward movement
	Trembling	Leg trembling but without effective forward motion
	Akinesia	No observable motion of the legs, despite the intention to walk
NOTES	Free text entry	Raters can use this to type in any text

4. How to score an event

4.1 - Selecting events

Events are selected by clicking on a tier with the left mouse button and dragging the red line until the end of the event, as per **Figure 2**.

For example if you want to mark the duration of a Timed up and Go (TUG) task, you will navigate the video to the start of the TUG, then click and drag the red line until the end of the TUG event and let go. An event area will appear in blue.

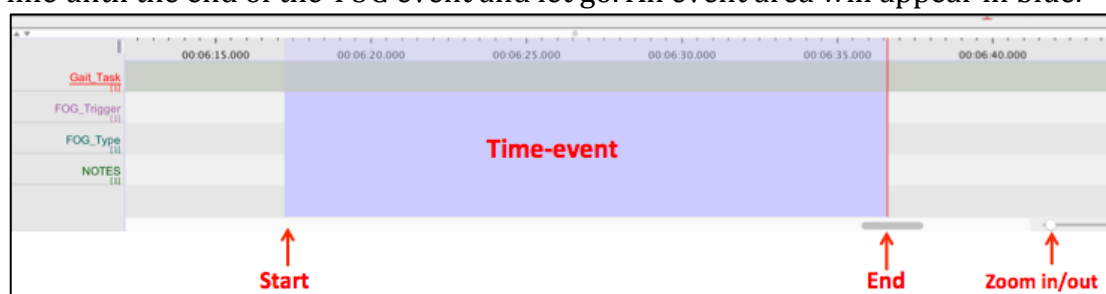


Figure 2 - Selecting a Time-event

TIP: Using the “**Zoom in/out**” button allows you to change the time interval. This makes it easier to score longer events, as it allows them to be displayed along the same epoch. It may be faster to first zoom out to score the events ‘roughly’ and afterwards to zoom in at the start- and end of each event to score the exact timing with millisecond precision, see *Chapter 4.3* below.

4.2 - Adding Annotations

After selecting the event, annotations can be added by double-clicking with the left-mouse button on the respective Tier within that event. For example, for adding a TUG annotation, double-click on the ‘Gait_Task’ Tier within your selected event area. A drop-down list will appear allowing you to select one of the pre-specified annotations by double-clicking on them, see **Figure 3**.

Pre-specified annotations prevent typo’s and thus allow you to quickly sort the output file. The FOG_scoring_Template contains frequently used annotations. It is, however, very simple to add, delete or change the annotations, see *Chapter 7*. The drop-down list also displays pre-specified descriptions of each annotation. The FOG_scoring_Template also contains a “**NOTES**” tier that allows for free-text entries by the rater, see **Figure 4**. This tier can be used to provide any notes, for example about deviations in performance of the participant. It can also be used

calibrate other devices (e.g. IMU, fNIRS, EEG) by noting down their zero-time points as recorded on camera, see *Chapter 8.1*.

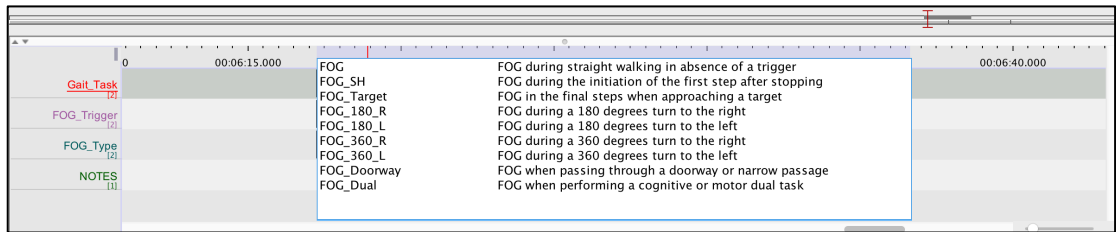


Figure 3: “FOG-Trigger” tier drop-down list with pre-specified annotations



Figure 4: “NOTES” tier with the option to enter free-text

After adding an annotation, the event is given the annotation name and changes to a color associated with that annotation, see **Figure 5**. Each event can be scored with multiple annotations, see **Figure 6**. This way annotations can be added to all events of interest.

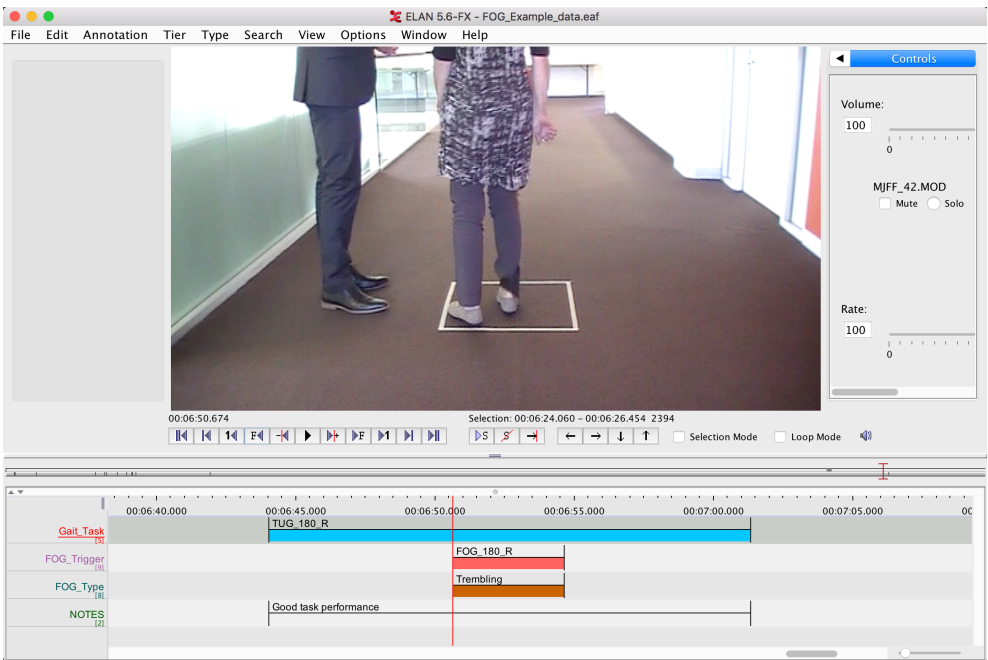


Figure 5 - Example of how to score a TUG with a 180-degrees turn to the right and a FOG episode during turning, characterized by trembling of the legs.

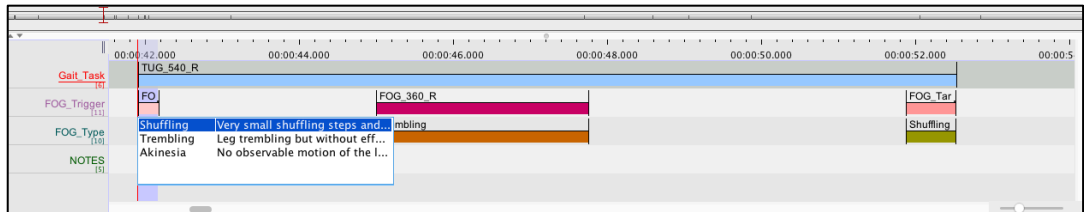


Figure 6 - Example of a scored TUG with a 540-degrees turn to the right and multiple FOG episodes with different triggers and FOG-types.

4.3 - Changing an existing annotation

- Double-click on the annotation to select a different annotation from the list.
- To delete annotations, right-mouse click on the annotation and select '*Delete Annotation*'.
- It is also possible to merge annotations. This can be helpful to change the start- or end times of an event without having to delete it. To do so, create another annotation with the correct start or end time, but instead of selecting an annotation from the drop-down list, this time, click anywhere outside the drop down list. This will create a 'blanco' annotation. Right-mouse click on this blanco annotation and select '*Merge with Next Annotation*' or '*Merge with Annotation Before*'. This will merge the two annotations and thereby change the start/end time of your original annotation, as per **Figure 9**. If you merge two labelled annotations, then you will see that their labels will also get merged. In this case, you can double-click on the event with the merged labels, and simply select the pre-specified annotation again from the drop-down list.

It may indeed be faster to first 'roughly' score all events and then to zoom in on the start- and end points of the gait task to set the exact start and end-points with millisecond precision using the merge function.

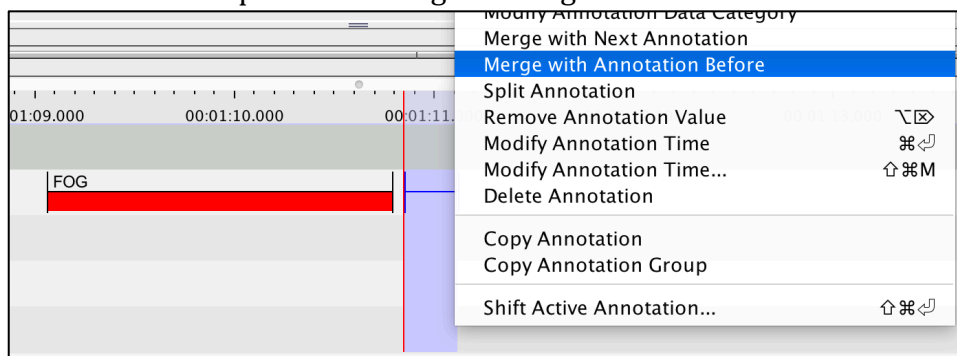


Figure 9 - Example of how to change the end time of an annotation by adding a 'blanco' annotation with the correct endpoint and then merging the two.

5. Save and Export

Save the project by selecting '**File**' and '**Save as**' from the main menu. This saves the project as an ".eaf" file, which can be opened in ELAN to continue working on the project at a later time if needed.

To export the outcomes, select '**File**' and '**Export as**' from the main menu. One option is to export it as a '*Tab delimited text file*' that you can then import into another software, such as MS Excel or Matlab.

A window will appear to select what values you wish to export. You can use the settings as presented in **Figure 10** below.

Press '**OK**' and save the exported output in the correct folder.

Export tier(s) as tab-delimited text

By Tier Names By Types By Participants By Annotators ▶

☒ Gait_Task
☒ FOG_Trigger
☒ FOG_Type
☒ NOTES

☐ Show only root tiers

Output options

☐ Restrict to selected time interval
☒ Add master media time offset to annotation times
☐ Include header lines containing media file information
☒ Exclude tier names from output
☐ Exclude participant names from output
☒ Separate column for each tier

- ☐ Repeat values of annotations spanning other annotations
- ☐ Only repeat within annotation hierarchies
- ☐ Sliced annotation output showing temporal co-occurrences
- ☐ Include the annotation id
- ☐ Include description from the controlled vocabulary

Include time column for:

- ☒ Begin Time
- ☒ End Time
- ☒ Duration

Include time format:

- ☒ hh:mm:ss.ms
- ☐ ss.msec
- ☒ msec

Figure 10: Export settings. Make sure all Tiers of interest are selected at the top.

6. Calculating %FOG

Each row in the output file represents an event that was scored (**Figure 11**):

Column A = Begin Time - hh:mm:ss.ms

Column B = Begin Time - msec

Column C = End Time - hh:mm:ss.ms

Column D = End Time - msec

Column E = Duration - hh:mm:ss.ms

Column F = Duration - msec

Columns G - J = Annotation labels

By deleting columns **B**, **D**, and **E** you can create the following structure:

	A	B	C	D	E	F	G	H
1	Begin Time - hh:mm:ss.ms	End Time - hh:mm:ss.ms	Duration - msec	Gait_Task	FOG_Trigger	FOG_Type	NOTES	%FOG
2	01:08.1	01:09.9	1818				Begin Time = zero time point right IMU	
3	01:12.8	01:14.4	1576				Begin Time = zero time point left IMU	
4	01:17.2	01:30.9	13727	TUG_180_R				$(C5 * 100) / C4 = 6.85$
5	01:22.8	01:23.8	940		FOG_180_R	Trembling		
6	01:45.2	01:57.8	12666	TUG_180_L			No FOG observed	0
7	02:17.2	02:33.9	16640	TUG_540_R				$((C9 + C8) * 100) / C7 = 12.0$
8	02:17.9	02:18.4	520		FOG_SH	Trembling		
9	02:24.8	02:26.2	1480		FOG_360_R	Trembling		
10	02:42.2	02:58.0	15880	TUG_540_L				$((C12 + C11) * 100) / C10 = 14.9$
11	02:49.0	02:50.5	1480		FOG_360_L	Trembling		
12	02:55.9	02:56.8	880		FOG_Target	Akinesia		

Figure 11: Example output obtained from the ELAN software.

Sorting the data file by column A ('Begin Time') will align the events in chronological order.

The **%FOG** can now be calculated for each gait assessment using the formula:

$$\%FOG = \frac{(Total\ duration\ of\ FOG\ observed\ during\ the\ gait\ task * 100)}{Total\ duration\ it\ took\ the\ participant\ to\ perform\ the\ gait\ task}$$

It remains up to the investigator's discretion to calculate %FOG based on all FOG episodes taken together, or to differentiate %FOG scores across the different phenotypes and/or triggers of FOG. This should be clearly stated when reporting the results.



7. Customizing the template

Investigators are free to amend the FOG-scoring template to match their own task designs and performance measures. For example, studies aiming to validate FOG detection algorithms from wearable sensor data against video observation might wish to add another Tier to annotate 'Good Event' periods, such as walking and turning without any observable FOG, and importantly, voluntary stopping. These events can then be used to verify the specificity (i.e. false-positive rate) of the FOG detection algorithm. So, say for example you wish to add another tier named '**Good_Event**' with predefined annotations, then you can do so by following these 3 steps:

1) Add Controlled Vocabulary (**Figure 12**):

- From the main drop-down menu select '*Edit*' and '*Edit Controlled Vocabularies*'.
- In '*CV Name*' type the name of the Tier you wish to create (e.g. 'Good_Event').
- Press 'Add'.
- In the bottom half of the screen you can now add predefined annotations. Type their names (e.g. 'Good_Walk') in the '*Entry value*' section and type out their descriptions in the '*Entry description*' field. Press 'Add' to add each annotation.
- Clicking on the annotation in the '*Entries*' field and selecting '*More Options...*' allows you to set the background colors, as well as create short-cut keys.
- Using the arrows you can change the order of the annotations.
- Press '*Close*' when finished.

Figure 12: Customizing the Controlled Vocabularies (=annotations)

2) Add Tier Type:

- From the main drop-down menu select 'Type' and then 'Add New Tier Type'.
- Fill out 'Type Name' (**Figure 13**)
- Select the corresponding controlled vocabulary you just created.
- *If you leave this to 'None' than a free text section will appear instead of a drop-down menu when selecting that tier.
- Select 'Add'

Type Name	Stereotype	Use Controlled Voc...	DC ID	Time-aligna...
Gait_Task	-	Gait_Task	-	✓
FOG_Trigger	-	FOG	-	✓
FOG_Type	-	FOG_type	-	✓
NOTES	-	-	-	✓
Good_Events	-	Good_Events	-	✓

Figure 13: Example of how to add a Tier Type

3) Add Tier:

- In the main drop-down menu select 'Tier' and 'Add new Tier...'
- Type in the Tier Name
- Under 'Tier Type' select the corresponding Tier Type you just created
- Select 'Add'

Now the new Tier is added to the main screen and when selected a drop-down menu with the predefined annotations will appear. The steps above can also be used to change or delete existing pre-specified tiers and annotations.

8. Standardizing the scoring of %FOG

For visual scoring of FOG to be used as a gold-standard outcome measure, it is of the greatest importance to standardize the scoring across raters and studies.

No consensus in the field currently exists on which gait tasks should be used in order to calculate the %FOG, so this remains up to the investigator's discretion. However, to use the %FOG as an outcome measure in a therapeutic trial, it is of the utmost importance to keep the type of gait tasks and the way they are assessed by the investigators highly consistent between the pre- and post intervention measurements. This includes the instructions given to participants, time and setting of testing, staff performing the assessments, positioning of the camera, medication status of the participants, etc. Also, make sure that the content of the video cannot cause the un-blinding of raters.

For an example of a standardized gait assessment used to calculate the %FOG using the ELAN software in a therapeutic trial, see Walton et al., (2018) [1].

From experience, I find it easiest to annotate video's that were recorded in a well-lit environment by a camera positioned on a static tripod placed so that the participant is walking straight towards the camera, with the task condition of interest (e.g. the turn during a TUG) occurring closest to the camera's position, for example, see **Figure 14**. Make sure instructions provided by the study assessors (e.g. "GO" or "STOP") are clearly audible on video.



Figure 14: Example of camera positioning during a standard 5-meter TUG task whereby the participant walks straight towards a taped square box on the floor in which the turning condition is performed.

Besides the type of gait assessment performed, the scoring of %FOG also depends on the definitions applied by the rater. Below, I present a table with definitions of how the onsets and durations of FOG and frequently used gait tasks could be scored from video recordings in a standardized manner (**Table 3**).

In **Table 4**, I also provide definitions of other gait features that are common in patients with FOG, but for now should not be included in the %FOG calculation.

Table 3: Definitions to standardize the scoring of %FOG from video.

Task/ Event	Start Time	End Time
Gait tasks that start-and end in a seated position (e.g. Timed up and Go).	The moment the subject lifts off from the chair (i.e. the buttocks no longer touches the chair). <i>*This is easier to score on video than the release of the back from the chair when the camera is positioned in front of the participant, as per Figure 14.</i>	The moment the subject touches back down on the chair (i.e. the buttocks touches the chair) after performing the gait task.
Gait tasks that start-and end from a standing position.	The moment the “GO” signal is given by the instructor. <i>*This allows start hesitation to be scored.</i>	The moment the participant returns to the starting position.
Turning after a period of walking (e.g. during a TUG).	The moment of <i>toe-off</i> at the start of the first step that touches down in the area where the turn should be performed with the foot pointing towards the direction of the turn.	The moment when the foot that leaves the area of where the turn was performed is touching down pointing towards the end target of the gait task.
Turning on the spot (e.g. during a 360 degrees turning task)	The moment the “GO” signal is given by the instructor.	The moment the participant returns to the starting position.
Freezing of Gait (FOG) Based on the definition of FOG by Nutt <i>et al.</i> , (2011) [5]	The moment when the foot of the participant is suddenly no longer producing an effective step forward and is displaying FOG-related features (trembling, shuffling, complete akinesia), despite the participant’s intention to continue walking.	The moment of initial toe-off after the FOG when the participant is again able to perform at least two effective alternating steps with both legs showing no FOG-related features. <i>For example, if during a FOG episode one leg is suddenly moving forward but the other leg is still showing FOG-related features, than this can be counted as the same episode.</i>

NOTE: These definitions are provided in an attempt to standardize the visual scoring of FOG from video footage across raters and studies. Regardless, researchers might choose to apply different definitions. It is therefore advised to clearly state the definitions applied when disseminating outcomes.

Table 4: Definitions of other gait features in PD patients with FOG that frequently require scoring, but for now should NOT be included in the %FOG calculation.

Task/ Event	Start Time	End Time
“Stops walking when talking/thinking (SWWT)” [6], e.g. during a cognitive dual task.	The first moment when the foot of the participant is no longer producing a step forward, but without any clear FOG-related features (i.e. participant ceased the effort to walk in order to think or talk).	The moment the participant’s foot lifts off from the ground to resume walking.
Festination type 1: Sequence effect [7]. <i>Although isolated festination without features of FOG should not be included in %FOG, be mindful that this type of festination often results in FOG.</i>	The first moment of toe-off when a progressive shortening of step length, accompanied by a compensatory increase in cadence is observed without any clear FOG-related features.	The moment of initial toe-off when the participant is again able to perform at least two effective alternating steps with both legs showing no FOG- or festination related features.
Festination type 2: Postural and Balance deficit [7]. <i>For now, isolated festination of this type without features of FOG should not be included in the calculation of %FOG.</i>	The first moment of toe-off when inappropriately small balance-correcting steps are observed that are a response to the forward leaning of the trunk.	The moment of initial toe-off when the participant is again able to perform at least two effective alternating steps with both legs showing no FOG- or festination related features.

9. Tips and trouble-shooting

1. Temporal Calibration

As aforementioned, the ELAN software can be used to calibrate the timing of the video recordings to the timing of any other device recorded on video. For example, the absolute zero time point on the output of many devices is set to when the device is turned on. In this instance, the devices can be turned on while being recorded on video. This way the zero-time points between the two outputs can be easily re-calibrated.

There are also other ways to calibrate. For example, for calibrating IMU’s, one could physically ‘tap’ these devices on camera, which creates recognizable peaks (i.e. marks) in the acceleration data. This thereby allows for the temporal synchronization between the onset of the peak acceleration and the time point of the physically applied tap recorded on camera. A similar option is to ask the participant to ‘stamp’ their foot three times on camera, which also creates an easily recognizable marking on the IMU data.

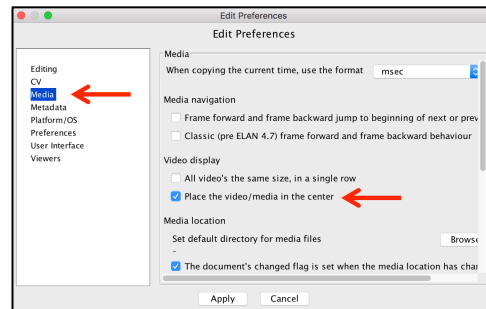
The “**NOTES**” tier can be used to define the begin times of such calibration events, see example output in **Figure 11**.

2. Video formats

ELAN cannot open all types of video files. Some files will first need to be converted (for instance to “.mp4”) before they can be opened in ELAN. There are many online applications that can be used to convert video files.

3. Changing video settings

The video may not appear in the center of the screen. If so, select ‘Edits’ from the main drop down menu and then ‘Preferences → Edit Preferences’. In this window under ‘Media’ you can tick a box to place the video/media in the center. You can also right-mouse click on the video itself and select ‘Force aspect Ratio’ to set it to a larger screen size (16:9)



4. Do not use space characters

It is advised not to add any space characters (i.e. ‘space-bar’) in the labels of Tiers and pre-specified annotations. Analyzing software, e.g. Matlab, often does not recognize spaces as input and as a result may not read or analyze the export file correctly. Instead, underscores (‘_’) can be used to link two words in a string as done in the present FOG scoring template.

10. References.

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