



Figure 2: Replay of one reading with 2-second scanpath tail overlaid. Book page © Gyldendal

Table 1: Distribution of teachers' notes on scanpath attention points.

<i>All marked misread words</i>		787
<i>All scanpath notes</i>		264
# of pre-annotations w. notes	% of pre-annotations w. notes	
Image	34	2.6
Longgaze	22	1.5
Peripheral	11	1.0
Shortgaze	9	0.4
Jumpback	8	0.5
Search	2	0.5

length (see e.g. Rayner et al. [2012] for an overview). While EyeJustRead supports data collection that may be used for analyzing these metrics as well, our current focus is in supporting reflective dialogs by use of scanpaths. The full, complex record of fixation order and durations was first introduced for analyzing reading development by Buswell [1922]. Since then, it has become one of the most common graphic forms used for visualizing gaze data; scanpaths capture fixation order, duration and the connecting saccades in one image that most people understand immediately.

Animating the saccade sequence by replay adds the time-dynamics intuitively to the scanpath. The replay function of the EyeJustRead tool displays the scanpath with a 2-second tail. The path is re-aligned vertically to the nearest line of text following a common strategy in reading research to re-align gaze data (see e.g. Topi et al. [2016]). When the scanpath is replayed in sync with the voice recording, it becomes possible for the reading teacher to build on years of professional practice in analyzing students' vocal reading and combine this with the new information contained in the gaze recording. For example, during a vocal pause, the scanpath may reveal whether the student is applying a relevant decoding strategy or their gaze seems to wander aimlessly. With the replay available, the reading teacher is further enabled to elicit the student's own thoughts through retrospective think-aloud. Some teachers actively use the recorded data to engage a student's parents by demonstrating intervention strategies and results using the scanpath replay.

4 SCANPATH ANNOTATIONS

During replay, the system automatically annotates six distinct kinds of "Attention Points" which are low-level gaze behavior patterns, namely image fixations, long dwells, peripheral reading, short dwells, re-visited words (i.e. "Jumpback") and search. Teachers can add notes to each pre-annotated attention point as well as to any other point during replay and can mark any word as misread.

We have collected summary statistics for 421 individual reading sessions performed by 147 children referred to special reading intervention in 22 Danish schools and special education centers. The median reading session spans 4 pages or 132 words and lasts 3 minutes and 2 seconds. Teachers made help features available in 87% of the readings. However, these features were used by the students in only 10% of the sessions. Table 1 shows the number of words marked as misread and the distribution of the notes teachers have added to the scanpath during replay. This reveals that image fixations and long dwells are the pre-annotated attention points that are most commonly used when teachers add scanpath notes. These two most popular pre-annotations together account for 21% of scanpath notes while teachers' 178 manually identified attention points for adding notes (e.g. with misread words) account for 67% of the total of 264 scanpath notes. However, most of the pre-annotated attention points, as well as most of the misreadings, do not get enriched with a note by the teacher.

By our observation, teachers are typically spending 10 minutes following up on a reading with a child. Teachers added summary notes describing a full reading session in 13% of the recorded readings, whereas they used the option to add scanpath notes during replay in 24% of the readings and marked individual words as misread in 29% of the readings. These numbers provide us with key metrics to further improve on teachers' engagement in the scanpath analysis; our future design and support may be compared to these baselines.

A reading teacher explained the possibilities that scanpath replays gives for supporting collaboration with the student and for communicating the students' progress to outsiders:

It is possible to document in detail the challenges, but also strengths, of a student. [...] When the replay is used in a conversation with the student, the student becomes aware of which strategies they employ, but can actually also often provide valuable observations and information about what they do or think when they read. [...] When there is a reading that you analyzed yourself, and talked through with the student, it is possible to determine much more precisely what should be the focus of the teaching.

5 CONCLUSION

The EyeJustRead tool was developed on the premise that eye tracking technology has matured enough and reached a price point which allow it to be widely deployed. While existing gaze-based reading research focus on controlled laboratory settings and analysis methods that are not practically applicable to reading teaching, we find that scanpath data provides a meaningful and novel contribution to this field of expertise.

